PROCEEDINGS

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THE ENGINEERS' CLUB

OF PHILADELPHIA.

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SOME CAUSES OF FIRE.

WASHINGTON DEVEREUX.

Read October 1, 1904.

THE subject before us this evening—"Some Causes of Fire"—is one of vital importance to people in every walk of life and yet but little understood by people at large.

Some recent large fires, however, have caused the thinking public to consider their surroundings and the probability of a conflagration in their immediate vicinity; also the possibility of lessening the enormous loss of property, which during the past ten years, reached the sum of $1,456,523,768 in the United States. The total loss in the United States during 1902 was $161,488,355. The total loss in the state of Pennsylvania during 1902 was $11,450,646, while the total loss in the city of Philadelphia during the same year was $2,152,971.

It is not my purpose to theorize much, but rather deal with the subject from a practical standpoint.

Among some causes of fire in Pennsylvania in 1902, with the resulting losses, might be mentioned, ashes and hot coals, bonfires, candles, and children playing with matches, $74,375; cigars, cigarettes, and pipes, $132,625; collisions (rail), $199,600; defective flues and heating apparatus, $1,712,300; electric wires and lights, $447,795; explosions from gas, gasoline, etc., $346,045; engines and boilers, $44,-650; forest fires, $157,950; friction in machinery, $218,230; furnaces,

$127,705; gas jets, $128,405; chemicals, grease, oil, paint, and varnish, $42,670; incendiarism, $1,790,875; lamp and lantern accidents, $180,-210; lightning, $373,630; matches, $157,850; oil stoves, $212,086; sparks within buildings, $451,690; sparks from locomotives, $119,-885; spontaneous combustion, $574,970; defective and overheated coal stoves, $660,405; tramps, $162,665; unknown origin, $3,875,260.

Ashes.—Hot ashes cast into wooden receptacles, which many times are resting on wooden floors, have been the origin of many fires. As a matter of fact, in some of our largest mercantile establishments some years since the practice was not infrequent to use a packing box as a means of storing ashes, regardless of their condition. This practice is fortunately passing away rapidly, due to the more modern methods of heating—hot water or low pressure steam. The apparatus, boilers, etc., are in the care of more careful attendants than formerly; furthermore, the heating apparatus is constructed along more modern lines, with due regard to the fire hazard and proper disposition of hot ashes. When properly constructed, hot water and low pressure steam are the safest methods of artificial heating.

In many institutions where each tenant supplies his own fuel, the coal stove prevails. In many buildings of from three to six floors, containing from thirty to one hundred employees to the floor, each floor representing a different class of manufacturing process, the disposition of ashes, hot or cold, is a source of trouble, due to the inconvenience of location and lack of accommodation to safely dispose of the refuse. The wooden receptacle is too frequently made to serve the purpose without regard to the hazard involved.

In all cases proper metal cans of readily portable size should be used. The parts should be riveted and well braced on the sides with metal strips, and supported on metal holders which will allow a free air space of at least six inches between the floor and the can.

Candles.—Candles when lighted should be always placed in a candle stick made of metal. Workmen very often will place a lighted candle on woodwork and if occasion requires they will go away with no thought of the lighted candle and its attending danger, many times causing a serious fire. Some years ago a large hotel in the city of Philadelphia considered the advisability of introducing electric lighting. A fire of a very mysterious origin occurred. The electric wiring had been installed in accordance with the best-known methods of the day, but the molding which incased the electric conductors caught fire. The proprietor had heard many vague and mythical stories of

the dangers of electricity and concluded the electric conductors were responsible for the fire, in spite of the fact that no current had ever passed over the wires. The problem was a great one and too much for "mine host." To solve the mystery he summoned to his aid a so-called electric expert. The expert declared the wires had been charged with induced electric current from the electric light mains in the street, which passed within fifty feet of the building. Mr. William McDevitt, Chief Inspector of the Fire Underwriters' Association, was also consulted. The theory of electrical induction did not appeal to him in the least. In fact, he knew the absurdity of the statement. Mr. McDevitt and the proprietor carefully went over the ground. The line of molding in the cellar, which inclosed the electrical conductors, was considerably burned. At various points along the molding, candle grease indicated what mode of illumination had been used to aid the workmen while installing the wiring. The Inspector called for a small piece of candle, and lighting it placed it upon the molding, suggesting to the proprietor, "now we will go away and forget the lighted candle, and you will have another fire due to the electric induction." The common sense solution won the day and the building was equipped with electric light throughout.

Cigars, Cigarettes, and Pipes.—The careless disposal of a lighted cigar has caused many fires; as have also cigarettes, especially of Turkish or tobacco of a like nature. Once lighted, they continue to burn until consumed. Often the smoker will place a lighted cigarette on a wooden table, mantle, sideboard, piano, chair, desk, window ledge, or any convenient place, with little or no thought of the danger involved until a possible accident occurs.

Smokers' pipes have caused many fires; less perhaps, however, than cigars and cigarettes. Workmen have sometimes placed lighted pipes in their coat pockets or overalls and placed their discarded garments in the drawer of a work bench or closet. Hours after the establishment had closed a fire would occur, sometimes with most conclusive evidence as to the origin.

Most fires from smoking have been due to persons smoking in bed or while reclining on a couch, falling asleep, and permitting the lighted tobacco to fall upon inflammable material. Fires from this source are usually attended with loss of life or physical disfigurement.

Cuspidors.—Boxes made of wood and filled with sawdust have caused many fires. A lighted cigar or cigarette thrown into a box filled with sawdust will often start the sawdust to fire and smolder.

The fire is not perceptible for some time, as it is not attended with a flame at the beginning. Slowly the fine particles of sawdust are carbonized until the sawdust assumes the condition of a hot coal. The course of the fire is always downward, finally burning through the box. Should the cuspidor rest on a wooden floor a fire is most likely to occur, especially if the ceiling below the floor is lined or lathed. The lighter woodwork would readily fire, and fanned by the draught between the joists would gain headway of no small proportion before discovered. All cuspidors should be made of metal and partially filled with water.

Collisions (Railway).—While the railway companies use every precaution, collisions do occur, frequently attended with fire. The heating of cars by steam and the removal of the coal stove has done much to lessen the possibility of fire at the time of collisions.

Defective Flues and Heating Apparatus.—Flues into which joists enter for support of flooring. This is not an uncommon condition in the older buildings. The joist slowly carbonizes and finally takes fire. All woodwork should be free from direct contact with the flue. Loose bricks often permit a spark to enter a crevice and ignite woodwork. Flues should be lined or treated with cement.

Coal Stoves.—Coal stoves should be mounted on substantial metal legs; sheet metal at least 36 inches square should be placed on the floor to catch live coals which may accidentally fall from stoves. The fire clay lining should be intact and the fire should not extend above the fire clay lining. The sections of stove pipe should telescope one into the other at least three inches. The improper connecting of stove pipes has been the cause of many fires, especially in dwellings. The stove pipe should be well supported at the junction of each section. The stove should be mounted at least six inches above the floor level.

Gas Stoves.—Defective rubber hose attached to gas stoves has frequently caused fires. Wherever feasible an iron pipe should be used.

Small gas stoves mounted on tables and work benches, for heating irons or cooking purposes, have caused many fires. When the irons or cooking utensils are placed on a lighted gas stove a great portion of the heat is forced downward, the table beneath is slowly carbonized, and a fire is most apt to follow. Many persons line the tables with asbestos or tin, believing they have removed the fire danger. While it is true the asbestos will not burn, it will transmit heat and set

fire to the wood it was intended to protect. The same may be said of tin. The space directly under the stove should be cut out and be replaced with a pan of metal to catch accidental sparks.

Hot-air furnaces should receive the same care as coal stoves. All pipes to be protected with an air-space where passing through woodwork, and where short pipes are in service, as in cases of heating the floor directly above the furnace, the pipe should pass through a non-combustible protector, such as slate. The pipe should be kept clear of waste paper and sweepings.

At least two registers should be so arranged that they could not be closed. The closing of all registers and a brisk fire in the hot-air furnace will often heat the pipes to a dangerous degree.

Explosions of Benzine and Alcohol.—Benzine, which is a light product of petroleum, should be kept in metal cans and never under any circumstance in glass vessels. The use of benzine by persons ignorant of its volatile nature has caused many serious fires and many deaths. It is extensively used in the cleaning of wearing apparel. The vapor is heavier than the surrounding atmosphere, and when used in a room or building with open flame lights, or where a stove or furnace is in operation, an explosion and fire are imminent. As a matter of fact, an open flame is not necessary to ignite benzine fumes. Frictional electricity will as readily ignite benzine fumes as will the spark from a coil ignite hydrogen gas or any other inflammable gas.

Cleaning and dyeing establishments use benzine in great quantities. To avoid as much as possible explosions and their attending dangers, the large copper pots in which the cleansing process takes place are permanently and effectively grounded or connected to the earth by heavy copper wire, securely fastened to a water pipe or plates of metal buried in the earth. By this means the hazard is somewhat reduced, but at the best it is great.

The rubbing together of two pieces of silk will cause frictional sparking and when benzine vapor is present an explosion will follow Many persons use benzine as a moth-proofing substance. The practice should be discouraged. The danger to life and property is too great. In the spraying of furniture and carpets with benzine, a chance spark from a carpet of fine grade would ignite the fumes with most disastrous results. There is scarcely a household, however, in this city, in which you would not find a bottle of benzine in size from four ounces to a full quart. The same hazard can be encountered in the use of gasoline. In the state of Maryland there is a law prohibiting

the use of gasoline, except for power purposes, and in my humble opinion is a most excellent law.

Explosion of Dust.—All organic substances in a finely divided state may become explosive. Sugar dust, dust in textile mills, sawdust, the dust of rice, spice, niter, sulphur, flour, malt, and grain mills. Coal dust is explosive and highly inflammable. Dust in tanneries, fur factories, paper mills. In fact, any organic or vegetable dust is liable to explode under favorable conditions.

Finely divided substances are not only acted upon more rapidly chemically, but also mechanically, than when in bulk; if, therefore, a substance is capable of uniting with oxygen when in the crude state, it will unite with oxygen with greater avidity when in a state of fine subdivision, when the gas has a greater surface to act upon. In other words, a substance which is combustible under ordinary circumstances will become more combustible, or be consumed by combustion in much less time, when finely divided than in a crude state.

Dust explosions are caused by an organic substance becoming so finely divided that it may by a spark or flame be instantaneously ignited, causing the rapid formation of gases of many hundred times the volume of the former dust, the tremendous, suddenly applied pressure of which causes the phenomenal force of those explosions so frequently experienced in our flour and malt mills, candy factories, etc. This pressure is increased through the heat generated by the combustion, which causes the further expansion of the resulting gases.

The questions to be determined for every kind of dust are: at what degree of humidity will it cease to explode, how finely divided each kind of dust must be in order to explode, and the temperature at the time of explosion.

The amount of moisture present in the atmosphere, or in the dust itself, has an important influence on the causes of dust explosions, and a certain degree of humidity for each kind of dust may be reached at which it is impossible to ignite or explode the same. In the more modern mills suction pipes are installed, and when properly operated greatly reduce the fire hazard.

Gas and Air.—The proportion of ordinary coal gas requisite to render common air explosive is from 8 to 11 per cent., varying to some extent as it may be more or less confined.

Several of the elementary bodies, and many of their most important compounds are, at ordinary temperatures, gases, or may be converted into them by the application of heat. There is no dis-

tinction of kind, but one of degree, between a gas and a vapor. Gases or vapors are liquids plus heat.

Forest Fires.—Few consider the possible devastation which a piece of oily waste thrown or accidentally dropped from a railway engine or car may cause; yet it is not an uncommon occurrence to notice the burning brush, grass, and waste which lies along steam railway systems throughout the country. These fires many times spread among timber lands of great value. There is only one means of extinguishing them. The method employed is identical with that used by plainsmen in extinguishing prairie fires.

A fire is started at some distant point toward which the original fire is traveling. This affords a clearing and leaves little but smoldering débris upon arrival of the greater fire, and a possible check to its further destructiveness.

Friction in Machinery.—It is from friction that a very large portion of the fires taking place in mills and manufactories are due, and this is especially the case throughout the whole of the textile industries and both in new and in old machinery. New machinery is peculiarly liable to heat at the bearings for some time after erection, while in old machinery the wearing away of bearings, cogs, etc., causes the shafting and other parts to joggle and sway irregularly, many times heating the bearings to the melting point, which, dropping upon combustible materials, immediately creates a fire.

Gas Jets.—One hundred and forty dwellings were among the buildings destroyed in Pennsylvania in 1902. An unguarded open flame is always a menace to life and property. Swinging gas brackets are best dispensed with wherever possible. Stops should be provided to prevent the open flame coming in contact with combustible material. Open flames beneath woodwork, if within three feet, should be protected by sheet metal curved downward, allowing an air-space of at least three inches. The possible blowing out of a lava tip must ever be taken into consideration. Accidents of this character permit the flame to shoot out quite a distance.

The hazard of the open gas flame could be greatly reduced by the introduction of *properly* installed electric lighting systems, especially in mills, factories, theaters, amusement halls, and hotels, and in dwellings where feasible. Many dwelling fires have been caused by the accidental contact of a gas flame with curtains or draperies. These have invariably been most disastrous.

Ignition of Chemicals.—There are many chemical compositions on

the market of a most dangerous character, which are sold without due regard to the hazard involved or precaution to the purchaser. The amateur photographer will purchase a can of "flash powder" without a thought of its deadly properties, and the dealer will sell without a word of caution. Flash powders consist of pyroxilin (guncotton) and magnesium powder, or lycopodium and other extremely fine powders, being used in conjunction with guncotton and other hazardous materials.

In 1889 the attention of Messrs. Wiley & Co., chemical manufacturers of this city, was called to the fact that the presence in their works of a number of cans of "flash powder" constituted a serious hazard. The firm decided to remove the dangerous material. The work being of an unusually risky character, Mr. Joseph Wiley gave the removal his personal supervision. Before the task was completed, however, a can exploded, instantly killing Mr. Wiley, two of his workmen being literally torn to pieces. Several other men were seriously injured and panic reigned throughout the works. A fire followed the explosion, which was subdued by the fire department of the city only after great damage had been done.

There are many articles of a chemical composition in every-day use in our households, which should be used with greater care and never near an open flame. Cleaning preparations, composed of benzine, alcohol, chloroform, and ether, an excellent preparation for cleaning gloves, silks, etc., but very hazardous. Liniments composed of chloroform, sulphuric ether, alcohol, oil of turpentine, camphor, etc.; polishing pastes and furniture polish. In fact, there is scarcely a house in this city that has not on hand at all times a bottle of benzine or gasoline. If these articles are indispensable, they should be kept in metal cans, which will permit only a very small portion to drop from the can when manipulated by means of a spring ejector, which automatically closes when not in operation. Neglect of the above precautions has been the cause of serious accidents and many deaths in households throughout the land.

Celluloid toilet articles, which are made by subjecting guncotton and camphor to hydraulic pressure. These articles are very combustible. Instances are on record of hair combs taking fire while adorning the head of a lady, who occupied a position before a burning grate, or in close proximity to an open gas flame. Celluloid ignites at a very low temperature—about 290° to 300° F.

Lanterns and Oil Stoves.—Fires from this source are invariably

attended with serious menace to life. The oil used may be of lawful flash test, which is 110 to 150. An oil lamp or stove carrying loose oil is more liable to explode when one-third filled than when the vessel is fully loaded, or a lamp or stove burning low is more apt to explode than when burning full. When the vessel is well filled there is small chance of gas formation in the tank. As the oil is consumed, gases form. The nearer the flame is to the base of the burner the greater will be the amount of gas formed. The least agitation may cause an explosion, and fire follows. Glass oil tanks are especially dangerous. The dropping of a lighted lamp, breaking of the tank, and spreading of burning oil have brought havoc and desolation into many homes. The kicking over of a lantern in the city of Chicago caused a loss of $75,000,000. In Philadelphia within the past ten years there were 3009 fires due to oil lamps and stoves, creating a loss of $296,999.44. In this city during 1903 there were injured 320 persons and 44 deaths, the result of coal-oil lamps and stoves exploding or otherwise causing fires.

If in the city of Philadelphia there is an average of 40 deaths per year, due to coal oil fires, it is fair to presume there are at least 50 deaths in every state and territory of the United States per year, which would mean 2550 persons whose deaths were due to coal oil fires.

Matches.—The careless disposal of a lighted match has been the direct cause of many fires. Lighted matches thrown into waste baskets, among shavings, etc., matches among rubbish and waste matter have frequently caused fires. This is due to the phosphorus on the match-head, which ignites at a very low temperature, 110° to 130° F. Rats nibbling matches have caused fires quite often.

Mischievous Children Playing with Fire.—Many cases of children having been severely burned, some fatally, is a fact too well known. If a child is in the habit of playing with matches, there is one remedy which can be tried with good effect. Dip a match in petroleum and place the match where you know the child will shortly find it. True to his nature he will strike the match; the oil takes fire very quickly; immediately the entire match is in flames, the child burns his fingers, and the lesson is learned. A burnt child dreads the fire is an old adage, but true. Such a course at times is necessary, and though apparently cruel it is kindness after all.

Steam Pipes.—The charring (or reducing to carbon) of wood, though by many considered as of little importance, is in reality a

very serious matter indeed. Where steam or hot-air pipes pass through woodwork a metal collar should surround the pipe, giving full air space of at least half an inch—one inch is preferable. In mills, factories, stores, etc., the sweepings of the floor should be carefully removed from these points of lodgment. Rats often build their nests in close proximity to steam and hot-water pipes, thus insuring warmth during the cold season. A few matches in the nest or pieces of oily waste and then a fire is apt to follow.

DISCUSSION.

The President.—In what proportion of cases is the evidence of the origin of the fire destroyed? It would seem from the statistics as though the origins of most fires were determined very definitely.

Mr. Devereux.—No, I should not say so, because fires of unknown origin go into millions of dollars. A fire must be of considerable magnitude to altogether destroy the possibility of learning its origin. We had a fire ten or twelve years ago on Market Street—Lippincott & Co.'s wool-house was totally destroyed. It appeared impossible to determine the origin of the fire, and yet we learned that the joists trimmed right into an adjoining chimney and had ignited combustible material on the other side of the party wall. The body of the fire seemed to have been there when the firemen first reached the building, but gained such headway, after the building was opened by the firemen, that there was a smoke explosion which shattered the building from end to end and drove the men out. Before the explosion occurred they could see the body of the fire principally at the point near the chimney. To tell just how one determines the origin of fire would be hard. It is a matter of experience—circumstances and conditions vary. As a matter of fact, there are scarcely two fires alike in their development.

The President.—About how often is the real cause found out?

Mr. Devereux.—I think the percentage is at least seventy-five.

Clayton W. Pike.—Mr. Chairman, I would like to ask Mr. Devereux a question in regard to electrical hazards which has occurred to me several times. During the past few years we have seen rather extensive changes in the methods of electric wiring, due principally to the use of iron or steel conduit incasing the wires. Formerly these wires were carried through the joists and partition work of the building, or as we have them here—carried in wooden molding. Do the statistics of the fire losses show any difference—any lessening in the loss by electrical hazard—due to this presumably very much safer construction? This construction is extremely costly as compared with the old methods—about double. Are we getting the benefit from it?

Mr. Devereux.—The metal conduit has been in service a short time only. The incasing of electrical conductors in metal conduits adds a protection from a mechanical standpoint. Electrically it is not as good as insulation placed on the wire, it can never be equal to that of dry air. Wires on porcelain knobs placed six inches apart in dry places is a very safe condition.

Mr. Pike.—There is in the statistics given no attempt to divide the losses

from the different classes of construction, and there is no attempt to compare the losses on the percentage basis either. Of course, there is vastly more electrical construction now than there was ten years ago. If the loss now is double what it was ten years ago,—the annual loss,—then I should say that the improved methods of construction had paid, because there must be much more electrical construction in the buildings than in those in which fires took place.

Mr. Devereux.—Those who are acquainted with the methods of fifteen years ago and who will compare those methods with the more modern construction used to-day will readily recognize the marked improvement. Wires were held in position by means of staples or wooden cleats or passed through holes bored in wood, unprotected, or even laid in V-shaped grooves cut in the joists and directly under the floor boards, being subjected to the worst kind of mechanical injury. The advancement of practice has provided non-inflammable, non-combustible tubes, knobs, switches, cut-outs, etc.

Mr. Sadtler.—To show the way in which heat will strike through apparently suitable thicknesses of insulating material without air circulation, I cite the following instance: I was doing some work with a so-called "Buffalo Dental Furnace" made of quite thick refractory material, the bottom being at least two inches thick. This rested upon four layers of one-inch wood with layers of asbestos spread between them. After having used the furnace for an afternoon I noticed that the bottom of the table upon which it rested was charred, and upon taking the furnace down, an examination showed that the layers of wood were completely carbonized except around the edges where the air of the room kept them cool and the wood of the table directly beneath the furnace also disintegrated.

Mr. Devereux.—Furnaces have been located on the second floor of a building and have burned through and have fallen to the cellar, the occupants of the house not being aware of the condition of the floor until it collapsed, due to the weakening of the joists. Heat is often transmitted through four or five courses of brick.

In conclusion, the subject of "Fire Hazard" is of such great volume that little can be said in the short time allotted. It was the purpose of this paper to touch upon such points as we are apt to meet with in our daily routine. Is it not our plain duty to assist in reducing the vast fire losses and, what is of more importance, to reduce the loss of life and suffering from this cause?

SOME APPLICATIONS OF WOODEN STAVE PIPE.

JOHN BIRKINBINE.

Read October 15, 1904.

Conduits which have been employed to convey water and other liquids embrace the ancient aqueducts, wood logs bored, the modern masonry aqueducts, cast-iron pipe, wrought iron or steel riveted or welded pipe, either with transverse or spiral joints, wooden bored pipe banded and coated, sheet iron and steel pipe with cement core, and later wooden stave pipe and reinforced concrete conduits. Modifications of the above and departure from the cylindrical core make quite a number of styles and forms of closed conduits.

The wooden stave pipe is not a new conception; in fact, its form of construction is quite old, for every bucket used is practically an illustration of the general method of assembling the parts. It has served as conduits of considerable diameter for flumes or penstocks, feeding water-wheels, etc., but most of these were staves of wood secured by a series of flat metal bands.

The wooden stave pipe to which attention is especially directed was developed by the necessities of mining in western America. The distances to which metallic pipe would have to be transported, the difficult country in which the pipe was to be laid, and other local considerations brought about the construction of this form of conduit, and while it is not expected to displace cast iron or riveted or welded steel or iron pipe, it is admirably adapted for long conduits laid in difficult territory or for those which must be constructed at a moderate expenditure of money.

The use of wooden stave pipe, in the form which will be described, has gone beyond the experimental stage, both in the quantities and in the sizes of the pipes laid and in the length of time some of these have been in use.

It has been my privilege to be personally associated with construction in which wooden stave pipe from 28 inches to 72 inches in diameter have been features, the variety of territory covered and the local topographic conditions having given opportunity for the use of this form of conduit under numerous and diverse conditions.

While the data presented relates primarily to the construction of

a line of wooden stave pipe six and one-half miles in length, along the Little Conemaugh River, near Johnstown, Pennsylvania, other installations and some difficult problems elsewhere will be referred to.

The pipe along the Little Conemaugh River was laid to control a supplementary supply pending the construction of the permanent features of a comprehensive water-supply for the industries of Johnstown. It varies from 44 inches to 36 inches in diameter, and while for most of the six and one-half miles of its length the pressure is light (the pipe being on regular gradients of 1 to 2 in 1000, closely approximating the hydraulic grade), there are inverted siphons under considerable pressure. For the most of the route of the pipe there is no wagon road in the Conemaugh Valley, the creek and the Pennsylvania Railroad occupying the limited space between the steep hillsides; however, roads make it possible to reach the valley at several points; but for most of the distance the road used had to be built, and was of a temporary character.

To handle cast-iron pipes weighing three to four tons each and connect them in a locality, such as that indicated, would have been a costly undertaking. The use of riveted steel pipe did not show to advantage, when the light head of most of the distance covered by the conduit, and the acidity of the water coming from coal mines, which might be expected when the flow of the streams was below the normal, were also taken into consideration. The water conveyed by this conduit is not for domestic purposes or for steam generation.

The total length of the wooden stave conduit along the Conemaugh River is 33,822 feet, of which 9209 feet is 44 inches in diameter, 21,458 feet is 42 inches in diameter, and 3155 feet is 36 inches in diameter, the diameters and grades being such as to secure equal deliveries. The pipe is made up of staves of fir, cut and milled in the state of Washington. They are from 12 feet to 30 feet long, about $5\frac{1}{2}$ inches, or over, in width, and $1\frac{1}{2}$ to $1\frac{5}{8}$ inches thick.

In the 36-inch pipe there are 22 staves, and in the 42-inch, 25 staves. The staves are held in place by $\frac{1}{2}$-inch round steel bands having a tensile strength of not less than 60,000 pounds per square inch, the actual breaking strain of the $\frac{1}{2}$-inch bands showing 12,300 pounds. On one end of the band is a button-head 1 inch in diameter, and on the other a thread $5\frac{1}{2}$ inches long, rolled into the upset end. The head of the band fits a recess in a malleable iron shoe, the other portion of the shoe receiving the threaded end after the band has encircled the assembled staves. Each band is "cinched" by means of a brace

which forces a nut against a washer, which in turn rests against the shoe. In this way the bands are adjusted to the required tension and the pipe made tight.

The banding is spaced to suit the various pressures, the maximum spacing allowed being 12 inches, center to center. Where the pipe is under heavy pressure the spacing is reduced until, at a crossing of the Conemaugh River, with a static head of 63 feet, the 44-inch pipe bands are $4\frac{1}{3}$ inches apart, and at a creek crossing, where the static head is 176 feet, the 36-inch pipe bands are $2\frac{3}{4}$ inches apart.

The contractor for the Conemaugh pipe line, C. P. Allen, C. E., of Denver, Colorado, used the following formula for spacing the bands:

$$\frac{600\ L\ P\ H\ F}{A\ B} = \text{number of bands per 100 feet,}$$

Where D = diameter of pipe in inches;
B = breaking strain of band (60,000 lbs. per sq. in.);
F = factor of safety (4);
A = area of bands ($\frac{1}{2}$ in. round = 0.19635 sq. in.);
H = head in feet;
P = pressure due to one foot (0.44 lb.).

Thus, for a 44-inch pipe, $\frac{1}{2}$-inch bands, and a 50-foot head, the number of bands per 100 feet $= \dfrac{600 \times 44 \times 0.44 \times 50 \times 4}{0.19635 \times 60{,}000} = 197.$

Another formula for the spacing of bands in the assembling of wooden stave pipes is from a paper by James D. Schuyler on the water-works of Denver, Colorado, to be found in the "Transactions of the American Society of Civil Engineers," volume xxxi.

$$N = \frac{1200\ D\ P}{2\ S}$$

Where N = number of bands per hundred feet,
D = diameter of the pipe in inches,
P = pressure in lbs. per sq. ft.,
S = safe working strain in lbs. per sq. in. for bands when threaded for use, determined by regular tests at the mills where they are made.

The following values of S give a factor of safety of about five in each case, or about one-fourth of the elastic limit:

$\frac{3}{8}$-inch bands, plain	S = 1000	pounds.
$\frac{3}{8}$-inch " upset	S = 1200	"
$\frac{1}{2}$-inch " plain	S = 2000	"
$\frac{1}{2}$-inch " upset	S = 2500	"
$\frac{5}{8}$-inch " plain	S = 3000	"
$\frac{5}{8}$-inch " upset	S = 3500	"

The staves are milled with inside and outside surfaces to curves representing the interior and exterior circumferences of the pipe, and the sides are cut with radial faces so that when assembled they may form a complete circle. On one of the side faces a small bead is formed by a notch in the cutting tool, and this bead is crushed under the strain of "cinching" to form a continuous water-tight joint. The butt ends of the staves are cut off square and slotted to receive clips,

Fig. 1.—Illustrates the Preliminary Construction of a Wooden Stave Pipe, Showing the U Form upon which the Lower Staves are Placed and also a Portion of the Circular Form which is Employed to Support the Upper Staves in Position. It also Represents the Preliminary Banding of the Formed Pipe. This was Taken in the Conemaugh Pipe Line.

which in the pipe under discussion were made of sheet steel No. 12 gage ($\frac{1}{10}$ inch thick), $1\frac{1}{2}$ inches wide, and slightly longer than the width of the stave. These clips are used in forming the end or butt joints, fitting into the slots in the ends of the abutting staves and projecting slightly into the adjacent staves. In some lines of wooden stave pipe, indurated fiber or thin strips of wood have been applied for the same purpose.

In forming the pipe, cradles of steel tubing, bent in U form, are

set in the ditch and the lower staves are placed in position; then upon these lower staves are placed tubes bent to the desired circles, but with ends not connected, and the form of the pipe is thus obtained. After the staves are held by sufficient bands the interior tubing is sprung together to remove it, and subsequently the necessary bands, spaced to meet the requirements of the pressure, are put in place; the pipe leveled to position; the cradles removed, and the necessary

Fig. 2.—Shows the Wooden Stave Pipe under Construction; the Workman in the Foreground Holding the Drive-stick which Another Workman Strikes, Forcing the Stick Back upon Abutting Staves, thus Making the Joint with the Metal Clip; Another Workman has the Brace for Cinching up the Bands in Place; Another Workman is Operating the Brace for Cinching up the Bands. This View was Taken Along the Little Conemaugh Pipe Line.

undertamping done. After this the "cinching" proceeds until the pipe is satisfactorily tightened. Each band is dipped in asphaltum, and after being placed the bands and shoes are painted to reduce the chances of rust.

Numerous interesting installations of lines of wooden stave conduits are in Colorado, California, Oregon, Washington, and in fact in all of the Rocky Mountain and Pacific States. In some cases the

pipes span streams, or cañons, and are suspended to or from the cañon walls, and traverse tortuous and nearly inaccessible routes.

A notable application of wooden stave pipe is in connection with what was designated as the Pike's Peak Plant, on Beaver Creek, Pueblo, which is now operated by the Pueblo and Suburban Traction and Heating Company. This plant consists of a dam, conduit line made of wooden stave and steel riveted pipe, and a power station equipped with Pelton water-wheels. Five and a half miles east of Victor, on the southern slope of Pike's Peak, a steel-faced rock-filled dam, 400 feet long and 70 feet maximum height, forms a reservoir with a capacity of 103,000,000 cubic feet, with a water surface 9081 feet above sea-level.

The drainage basin tributary to this reservoir covers 61 square miles. The power house, 26,000 feet distant, has the floor of its tail race at 7909 feet elevation. The wooden stave pipe line is 30 inches in diameter and 23,200 feet long, and is formed of redwood staves $1\frac{1}{2}$ inches thick, secured by $\frac{1}{2}$-inch round steel bands and malleable iron lugs, the spacing between bands ranging from $2\frac{1}{4}$-inch to 8-inch centers. The pipe line is through an exceedingly rough country, with numerous curves; three of 100 feet radius and one compound curve with 35 feet radius. It has two inverted siphons where the static head is 215 feet. The pipe passes through a tunnel 1533 feet in length, cut through solid granite. Near the lower end of the tunnel is a stand-pipe 73 feet high, built of wooden staves, and for a portion of the distance the pipe is suspended from cables. The wooden stave pipe ends where the static head is 120 feet and connects with a riveted steel pipe 29 inches in diameter and 2900 feet long, constructed of plates from $\frac{1}{4}$ to $\frac{3}{4}$ inch thick, laid upon grades varying from $12\frac{1}{2}$ to 57 per cent. This pipe passes through a granite tunnel 335 feet long and then on to a bridge 70 feet high, both on 40 per cent. grades. The power plant units consist of two steel Pelton wheels on one shaft, each 66 inches in diameter, the connections to the generators being through a 7000-pound fly-wheel 7 feet in diameter. These wheels operate under a head of 1152 feet. This interesting installation was designed and constructed by R. M. Jones, C. E., of Denver, Colorado.

The relative cost of the different kinds of conduits depends on location, character of the country through which they are laid, pressure to which the pipes are subjected, and the size of the pipes. The conditions must be unusually favorable for wooden stave pipes less than 16 inches in diameter to be recommended.

The following statements suggest the approximate cost of wooden stave pipe:

An 18-inch pipe at Astoria, Oregon, 7½ miles in length, cost \$0.91 per foot in place, with lumber at \$35.00 per thousand and steel bands at \$0.048 per pound. Mr. A. L. Adams states that the details of cost are as follows:

"Steel in bands, \$0.048 per pound; lumber, feet B. M. in staves, measured before milling, \$35.40 per thousand. The cost to the city,

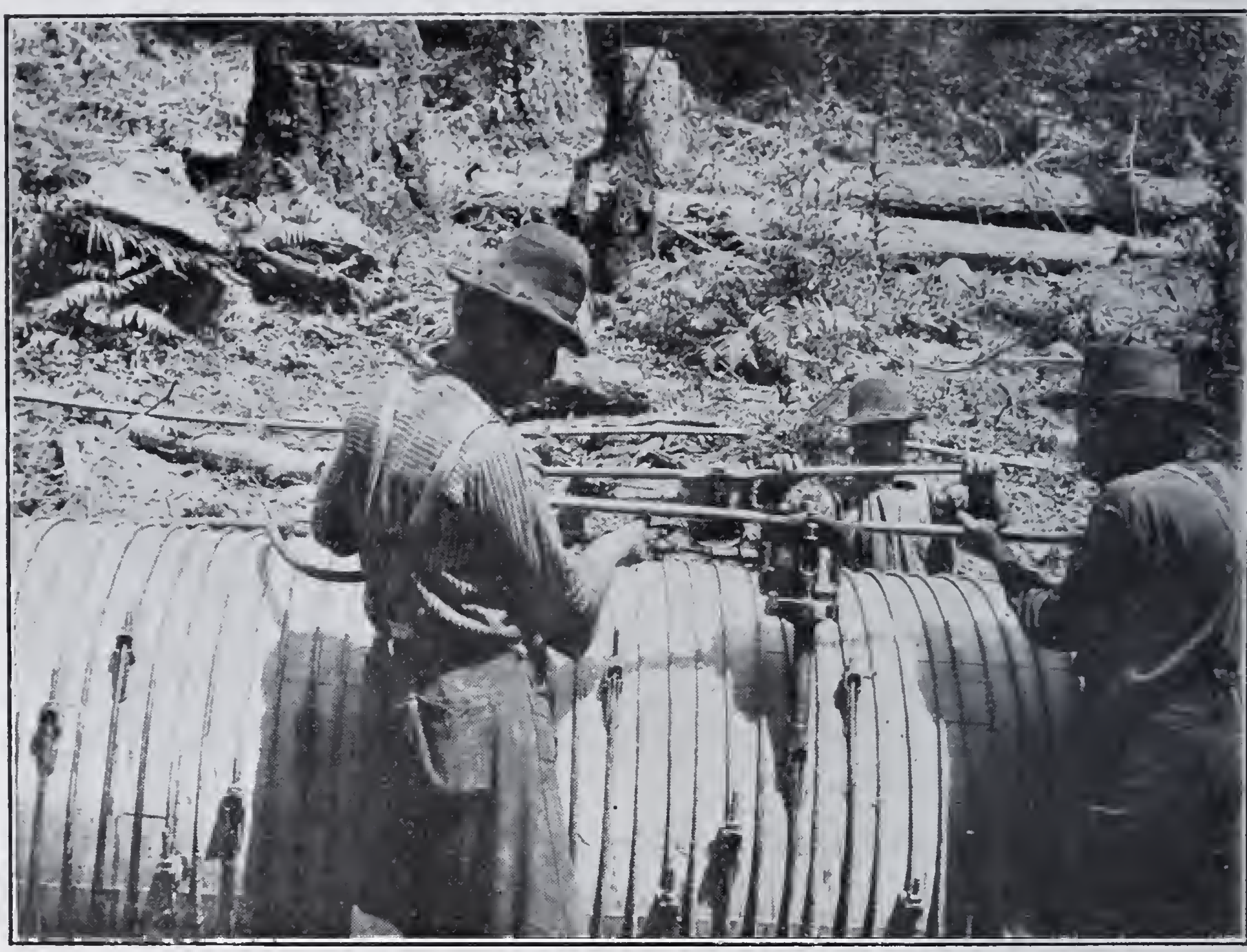


Fig. 3.—Illustrates Final Cinching on a Closely Banded Pipe near Seattle, Wash., Showing a Different Form of Cinching Apparatus.

including all appurtenances, was \$0.903 per foot; and \$0.76 excluding such appurtenances. The whole amount of the contract was \$36,100, and the total extra work cost \$29.35."

The distribution of the cost was as follows:

"Building and spacing bands, 55 per cent.; back-cinching, 26 per cent.; repainting iron work, 3 per cent.; back-filling to a depth of 6 inches over the pipe, 8.75 per cent.; placing specials, 3.5 per cent.; placing air-valve, 0.75 per cent.; unclassified labor, 3 per cent."

For the riveted steel pipe in the same line he gives the price per foot paid by the city as:

Size.	Gage of Steel.	Price.
14-inch	No. 12	$1.10
16-inch	" 12	$1.18
16-inch	" 10	$1.38

The cost of manufacturing the riveted steel pipe was about 0.45 of a cent per pound for labor only, including the cost of the dipping.

In Colorado, 5½ miles of 28-inch wooden stave pipe, under a head starting at 20 feet and ending at 150 feet, cost, exclusive of ditching, $1.67 per foot. The cost of the 6½ miles of 36-inch to 44-inch pipe along the Little Conemaugh River, exclusive of ditching and supports, approximated $2.60 per foot.

In 1903, 9807 feet of 42-inch wooden stave pipe was constructed at Absecom, N. J., for the Atlantic City water-supply. It was laid on its hydraulic gradient, requiring no heavy banding. The total cost of this line was $30,230.20, and the contract price of the pipe laid in the ditch was $2.25 per foot.

The relative costs can hardly be estimated unless the pressure under which the pipe is to be used is known. Where the pressure is light, or where the pressure averages light, there the wooden stave pipe of large diameter shows a decided economy, because of the small number of bands. As the pressure increases, the bands must be placed closer, and then the cost more nearly approaches that of steel riveted pipe. In all steel riveted pipes, even where the pressure is light, it is necessary to use metal of sufficient thickness to make the pipes rigid enough to prevent collapse, and where the ground is at all treacherous, it is also advisable to increase the banding of the wooden stave pipe to give it ample stability.

In 1898, Mr. A. L. Adams made a comparative estimate of cost of the three kinds of pipe in Chicago and San Francisco. The figures are supposed to include only the principal items of expense, with no profit to the contractor or incidentals, and are, therefore, perhaps in every case, below probable cost and are intended for comparison only. The figures made for Chicago are appended below.

In computing the following tables wooden stave pipe was assumed to be constructed as above described. Steel pipe was supposed to be double-riveted on the flat seams, and single-riveted on the round seams, as ordinarily built, and coated with asphalt. The mill price for sheet

steel was taken at from $1.60 for No. 14 plate to $1.25 for thicknesses greater than No. 8. The cast-iron pipe was supposed to be proportioned, as to thickness, according to the formula of the Warren Foundry, and the price per ton assumed was $19.00.

COMPARATIVE COST OF PIPE AT CHICAGO, INCLUDING LAYING, BUT OMITTING HAUL.

WOODEN STAVE PIPE.

Diameter.	25-foot head.	50-foot head.	100-foot head.	200-foot head.
12 inches..	$0.42	$0.49	$0.63	$0.85
18 " ..	0.69	0.80	1.02	1.46
24 " ..	0.79	0.91	1.14	1.61
30 " ..	0.96	1.12	1.44	2.06
36 " ..	1.19	1.40	1.82	2.65
42 " ..	1.40	1.68	2.23	3.33
48 " ..	1.55	1.85	2.46	3.67
54 " ..	2.23	2.62	3.43	5.02
60 " ..	2.85	3.35	4.37	6.40
66 " ..	3.21	3.81	5.00	7.38
72 " ..	3.65	4.38	5.83	8.73

RIVETED STEEL PIPE.

Diameter.	No. 14.	No. 12.	No. 10.	No. 8.	No. 6.	$\frac{1}{4}$ in.	$\frac{5}{16}$ in.	$\frac{3}{8}$ in.
12 inches..	$0.32	$0.38	$0.44	..	..	..	..	..
18 "	.. ..	0.57	0.65	$0.78	$0.98	..	..	..
24 "	.. ..	..	0.85	1.04	1.28	$1.55	$1.99	..
30 "	.. ..	..	..	1.27	1.59	1.93	2.46	$3.04
36 "	.. ..	..	..	1.55	1.93	2.30	2.92	3.58
42 "	.. ..	..	..	1.61	2.18	2.66	3.37	4.12
48 "	.. ..	..	..	..	2.48	3.03	3.83	4.66
54 "	.. ..	..	..	..	2.80	3.41	4.29	5.21
60 "	.. ..	..	..	..	..	3.79	4.75	5.74
66 "	.. ..	..	..	..	..	4.35	5.21	6.29
72 "	.. ..	..	..	..	..	4.52	5.66	6.83

CAST-IRON PIPE.

Diameter.	25-foot head.	50-foot head.	100-foot head.	200-foot head.
12 inches..	$0.73	$0.77	$0.84	$1.00
18 " ..	1.29	1.35	1.46	1.70
24 " ..	1.91	2.00	2.18	2.55
30 " ..	2.67	2.80	3.07	3.61
36 " ..	3.47	3.67	4.06	4.85
42 " ..	4.42	4.69	5.22	6.28
48 " ..	5.50	5.84	6.53	7.92
54 " ..	6.65	7.10	8.00	9.78
60 " ..	8.04	8.63	9.80	12.13
66 " ..	9.51	10.16	11.55	14.05
72 " ..	11.32	12.00	13.26	16.00

Mr. Adams considers that the life of wooden stave pipe is much in excess of that of light gage steel, that its carrying capacity is much greater at the beginning and is far more likely to remain practically constant, and that its transportation over rough roads is comparatively easy and the cost relatively low.

His comparison of the relative values of wooden stave, steel riveted, and cast-iron pipe places wooden stave pipe as the cheapest, steel riveted ranking next, and cast-iron pipe as most expensive. As to

Fig. 4.—Shows a Portion of the Heavily Banded Pipe Laid to Connect with the Power Station of the Pike's Peak Power Company, Illustrating some of the Bends and Specialties of Construction.

the life of the pipe, cast-iron is given first place, wooden stave second, steel riveted third, and as to the capacity, wooden stave has the largest, followed by cast-iron, and steel riveted the smallest.

We know that the life of cast-iron pipe, unless the pipe is subjected to acid water or to electrolysis, is yet undetermined, and if the staves of the wooden conduit are kept continually wet, its life may also be considered as undetermined, for 60 miles of wooden stave pipe, varying in diameter from 12 inches to 48 inches, are used in connection

with the water-supply of Denver, Colorado, under heads ranging from 10 to 210 feet, some having been in place more than 20 years, and other similar instances could be mentioned.

Fig. 5.—Illustrates the Portion of the Wooden Stave Conduit of the Pike's Peak Power Plant where it Emerges from the Tunnel and is Carried in Suspension. A Standpipe, also Wooden Stave, is Shown. The Derrick on the Rocks is Utilized to Handle Material from the End of the Roadway Down to the Railroad, which Extends to the Power House, a Distance of 3100 Feet, in which Distance there is a Drop of 1165 Feet. The Cars upon the Railroad are Operated by Cable.

The well-formed wooden stave pipe, laid as a continuous tube, may also be expected to present less obstruction to the flow of water than cast-iron pipe, and certainly less than steel riveted with the rivet heads projecting.

In a series of tests carried on at the Puget Sound Navy Yard in 1901, comparing Douglas fir and yellow pine for pipe staves, Mr. Frank W. Hibbs, Naval Constructor of the United States Navy, arrived at the following conclusions:

"In strength Douglas fir is generally equal to yellow pine and superior to it in some essential particulars.

"Douglas fir is decidedly more elastic than yellow pine.

"Douglas fir is far superior to yellow pine as regards to toughness.

"Yellow pine is superior to Douglas fir in wearing qualities, especially when moisture is present.

"Yellow pine is superior to Douglas fir in lasting qualities, on account of the greater amount of pitch it contains.

"Douglas fir is 14 per cent. lighter than yellow pine.

"Following are the average general characteristics of strength of Douglas fir:

"For well-seasoned, fine-grained, hard, clear stock,

Tensile strength,	13,000	lbs.	per sq. in.
Tensile strength across grain,	350	"	"
Tensile strength for bending,	10,000	"	"
Elastic limit for bending,	6,000	"	"
Modulus of elasticity for bending,	1,500,000	"	"
Strength for compression across the grain without destructive deformation,	1,200	"	"
Modulus of elasticity for compression across the grain,	4,000	"	"
Crushing strength for compression, "end on" to grain,	9,000	"	"
Modulus of elasticity for "end on" compression,	70,000	"	"
Modulus of elasticity for torsion,	27,000	"	"
Shearing strength with the grain,	15,000	"	"
Crushing strength for columns whose proportions are such as to resist bending,	6,000	"	"
Weight per cubic foot,	35 lbs."		

DISCUSSION.

Harrison Souder.—I believe that wooden stave pipe is well adapted for use in certain localities, where, as at Johnstown, the country is mountainous and rough and where it is a most difficult and expensive matter to transport the heavy cast-iron or steel pipe through the woods and across deep ravines. For the locality mentioned and for the western country, where the pipe is extensively used, there is nothing better. The staves can be packed on mule back and carried through regions where the cost of handling other kinds of pipes would be prohibitive. The bands are transported in the same way and the

pipe assembled in place in the ditch. Another good feature about it is that, with a sufficient length of ditch open, several pipe-laying gangs can be worked and the various sections carried on at the same time and joined as they meet, with very little trouble. Of course, in laying other pipes we can do the same thing, but with cast-iron pipe it would be difficult and rather expensive, and this objection would apply even more strongly to riveted steel pipe. From my own experience in getting large sized cast-iron pipe through the woods, a very large item of pipe-laying expense is transporting and distributing the pipe along the line.

As regards leakage from wooden pipes I have no data convenient at this time. It is not, however, excessive after the pipe has been in service some time.

The pipe at Johnstown is giving satisfaction, though some trouble was experienced in laying it. This was largely due to the fact that the contractor left his trenches open and pipe uncovered too long. On one or two occasions the trenches were flooded by rains and the empty pipe lifted a foot or more; several land-slides, too, caused much damage.

With a properly located line and the pipe well laid, wood stave pipe is satisfactory and economical.

John C. Trautwine, Jr.—Mr. Hawley tried to have wooden stave pipe adopted for the pumping main across the meadows from Pleasantville to Atlantic City, but he was overruled and steel pipe was laid. Mr. Souder has referred to the advantage of wooden stave pipe in difficult countries, such as that near Johnstown. There would hardly seem to be much difficulty in laying pipe on the Atlantic City meadows. I would ask whether wooden stave pipe would have any special advantages there. I suppose there must be some advantage which makes wooden stave pipe preferable to cast-iron pipe.

J. L. W. Birkinbine.—The advantage is that the coefficient of resistance of the wooden stave pipe is very low—the coefficient of resistance of cast-iron and riveted steel pipe increases each year, while in wooden stave pipe it decreases. A sort of slime forms and the pipe gets worn smooth by the action of the water. In Kutter's formula the factor of resistance is generally taken as 0.010 for wooden stave pipe, while for cast-iron as 0.013. From actual test I understand it has gone as low as 0.007 for wooden stave pipe, and that may be one reason why they should adopt it at a point like Atlantic City.

Mr. Souder.—My impression is that it is a gravity pipe line, and under the controlling features it is probably a fact that the friction is much less. It seems to me preferable to a steel pipe on account of the salt water. There is less corrosive action upon it. The steel bands upon the pipe will, of course, corrode, but they can be renewed easily and can be made of larger section, and, moreover, when there is so little pressure on the pipe as in this case, the bands can be spaced wide apart and the amount of metal subject to possible corrosive action is small compared with that in a steel pipe similarly placed.

The President.—This brings up the question whether the bands around those pipes have to be made strong enough to stand the original tension put on them by the tightening bolts plus the tension due to the water when the pipe is in use.

Edgar Marburg.—The initial tension in the bands produces compression in the wooden staves. The internal pressure of the water tends to relieve this

compression, thereby causing an enlargement of diameter which will produce additional tension in the bands. The final stresses in the staves and bands depend on the relative elastic behavior of the two materials, and for given data these stresses may be readily computed.

HENRY H. QUIMBY.—The enlargement of the pipe with its consequent increased length of band is necessarily attended with increased stress in the band. If the materials of construction were all absolutely without elasticity, there would never be any combination of initial and load stresses; but with elastic material the initial stress produces deformation, and the deformed material—compressed or stretched—is constantly exerting force in the effort to resume its normal dimensions. Whether the load will increase the initial stress or not depends upon how it is applied—whether it acts directly or indirectly against the elasticity of both the stressed parts. There are bridge details where the load stress is not affected by the initial stress; for example, a floor-beam suspended in adjustible stirrups in the old style. In the stave pipe the initial tension in the band stretches the band and compresses the staves. If all the bursting force exerted by the water pressure could be applied between the edges of the staves it would act directly and only against the elasticity of the staves and not increase the stress in the band; but as it is applied to the surface of the staves, acting to push them out and increase the diameter of the pipe, the result must be a combination of the springing elasticity of the staves and the bursting force of the water. As this combination increases the stress in the band, the band lengthens until the lessening force of elasticity attending the expansion of the staves restores equilibrium. The amount of increase in stress and in length of band will depend upon the moduli of elasticity of the two materials together with the ratio between the initial stress and the applied load. Of course, if the load, or pressure, should be enough greater than the initial stress to stretch the band beyond the elastic reaction of the staves, then the maximum stress in the band is only the pressure load, not at all increased or affected by the initial stress; but then the staves would be separated and permit water to escape. In view of this it is clearly necessary to adjust the bands to an initial stress considerably greater than the bursting effort of the water, because in order to prevent leakage the staves must be actually compressed edgewise even when the pressure is against them; therefore the band formula which considers only the amount of the direct stress produced by the water pressure, ignoring the necessarily superior initial stress and the swelling of the wood from moisture, is scarcely complete.

J. KAY LITTLE.—Does the thickness of the stave vary with the diameter of the pipe?

MR. H. E. BIRKINBINE.—Yes, but not materially. It varies according to the size of the pipe and also according to the hydrostatic pressure. These variations in thickness, however, are slight; thus, for a 36-inch pipe the thickness of the stave is 1½ inches, while for 42-inch and 44-inch pipe it is 1⅝ inches—a difference of only ⅛ inch. Although in some cases the staves are made thicker when the hydraulic pressure is great, the strength of the pipe is generally maintained by increasing the number of bands per foot. Connections are made between different sizes or the same sizes of pipe in a way similar to that used with cast-iron pipe; that is, the wooden stave pipe is connected with cast-iron

branches or breeches where the large pipes are connected, and by means of cast-iron bonnets or sleeves where a small pipe is connected with a larger one.

J. W. Ledoux.—I understand that wooden pipe is not satisfactory for more than 200 feet head. It is always easy in the mountains to provide a standpipe, and in California and other places I have seen standpipes used quite often.

C. P. Birkinbine.—As mentioned in the paper, the upper portion of the Pike's Peak line is made of staves, until a static head of 120 feet is reached (although in some places where there are inverted siphons the pipe is subjected to a static head of 215 feet), and has on the line a water-tower 73 feet high made of wooden staves. The lower portion of the line is of riveted steel pipe of thickness varying from $\frac{1}{4}$ to $\frac{3}{4}$ inches. This is necessary, as the turbines operate under a head of over 1150 feet.

COMMUNICATED DISCUSSION.

THOMAS C. MCBRIDE.

The Coolgardie gold fields in West Australia are supplied with water through a 30-inch pipe line, about 330 miles long, of the Mephan-Ferguson locking-bar type.

This pipe consists of two sheet steel plates of the length required for a length of pipe and a width of one-half of the circumference. The long edges of these plates are upset on a special machine, forming of these edges half of a dovetail. The plates are then bent into semicylindrical form and "locking bars" used to form the longitudinal joint. These locking bars are of approximately circular cross section and supplied with two grooves on opposite sides, wide enough to receive the upset edges of the sheets. After the length of pipe has been thus assembled, the grooves of the locking bars are closed on the edges of the pipe by means of hydraulic machinery, thus completing the length of pipe. The joints between lengths are made with forged steel sleeves caulked with lead. Each length was about 28 feet long, made of plates $\frac{1}{4}$ inch thick, and weighed about $1\frac{1}{4}$ tons. In some sections, where extra pressure existed, the pipes were made of $\frac{5}{16}$-inch plates. Sixty thousand pipe lengths were required, and the total estimated weight of steel plate was about 76,000 tons. The contract for this piping was signed October 24, 1898, by two Australian firms: Messrs. Mephan-Ferguson and Messrs. Hosking Brothers, who erected special works in West Australia for completing the pipe. The contract price for the pipes delivered at the works in West Australia amounted to £1,025,000. Each pipe was subjected to a hydraulic test pressure of 400 lbs. and then immersed in a bath of hot

Trinidad asphalt, in which it was kept until the temperature of the steel rose to that of the bath itself.

The capacity of the line was 5,600,000 gallons per twenty-four hours, and the estimated cost of the plant was set down at £2,500,-000, exclusive of any connections to towns en route.

There were eight pumping stations on this line, the first four delivering against total heads, including friction, in the neighborhood of 450 feet; the balance against about 225 feet, including friction.

The first four stations each had three Worthington triple-expansion, surface condensing, high-duty pumping engines, each of half the capacity of the line, so that one was in spare. The balance of the stations each had two engines, each of which was of the full capacity of the line; and the stations were so placed that the horse power of all of the engines in the plant was the same—about 300 I. H. P., —thus permitting of the same sized steam cylinders throughout.

PARKS AND PARKWAYS.

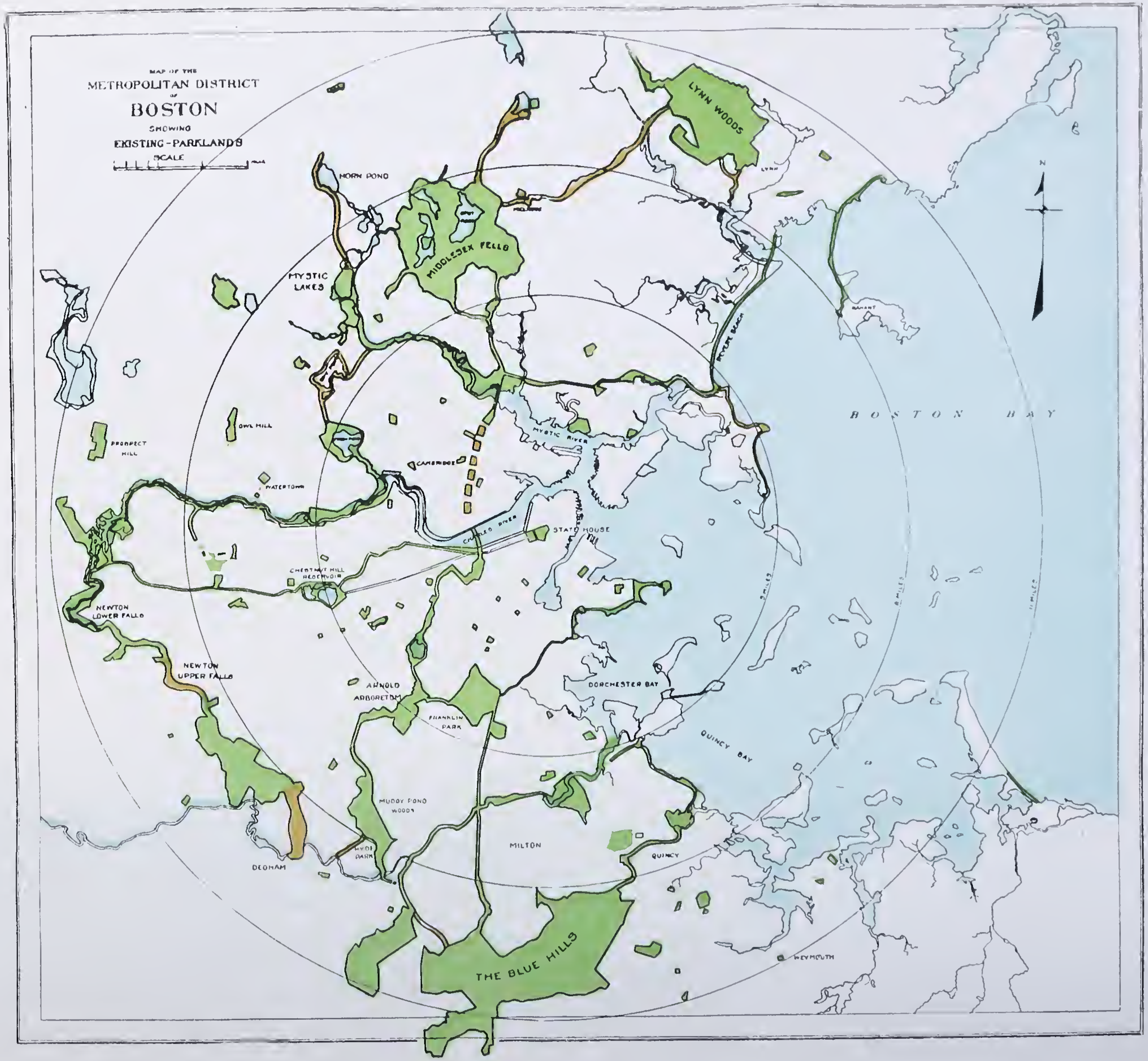
ANDREW WRIGHT CRAWFORD.

Read November 5, 1904.

THE movement for park systems did not spring into being in the last decade. It was slowly gathering force during the last half of the last century, when the nucleus of Fairmount Park, for instance, was secured by the acquisition of the Fairmount waterworks; but the early park movement which culminated in the "seventies" in securing Fairmount Park here, Franklin Park in Boston, and Central Park in New York, failed to provide big parks for more than one section of the city. The movement which began in the early "nineties" of the last century for co-ordinated systems of parks is decidedly different in that regard. Springfield, Illinois, has within the last year or two appointed a commission, and that commission states in its first report that it has determined not on one park for one section of the city, but on four parks at its four corners, so to speak, with park connecting links. It is the object of the present movement to locate parks where the people can get at them. The movement, which was at first called "an outer park movement," is becoming "a comprehensive park movement"; that is, a movement which stands not only for the acquisition of large outlying reservations, but for the smaller breathing spots which have been wisely called the lungs of the city.

The year 1893 marks the definite beginning of the present agitation. In that year Kansas City had practically no parks and no boulevards. A plan for a park system was suggested and a commission was appointed. Since that time a complete park system has been secured which covers over 2000 acres of parks, which are connected by ten and a half miles of constructed boulevards, or parkways, and which will be further connected by nineteen miles of parkways, the land for which has been acquired.

Kansas City has perhaps the most complete system that has so far been acquired, with the exception of Boston. That Boston has acquired a great park system is becoming more and more known, but it seems to us important to bring home the fact that Boston is only one of a very considerable number of American cities that are actually at work upon their park systems. The example of Kansas


MAP OF THE
METROPOLITAN DISTRICT
OF
BOSTON
SHOWING
EXISTING-PARKLANDS
SCALE
LYNN WOODS
LYNN
HORN POND
MIDDLESEX FELLS
MYSTIC LAKES
REVERE BEACH
NAHANT
BOSTON BAY
MYSTIC RIVER
CAMBRIDGE
OWL HILL
PROSPECT HILL
WATERTOWN
CHARLES RIVER
STATE HOUSE
CHESTNUT HILL RESERVOIR
NEWTON LOWER FALLS
NEWTON UPPER FALLS
ARNOLD ARBORETUM
FRANKLIN PARK
DORCHESTER BAY
QUINCY BAY
MUDDY POND WOODS
MILTON
QUINCY
HYDE PARK
DEDHAM
THE BLUE HILLS
WEYMOUTH

City has had a marked effect upon the cities near it, such as Memphis, St. Louis, and other cities of the middle west.

The map of Boston shows perhaps with exceptional distinctness the meaning of the word "system" as applied to parks. Instead of separate parks scattered here and there wherever opportunity may have offered, we find the Boston system showing the result of a careful consideration of the topography of the country within eleven miles of the State House. This has resulted in large parks, any one of which may be reached by attractive streets with grass plots in their centers or at their sides. It is the custom to call these connections "boulevards," but the word "parkway" seems more appropriate, as they are really parked ways leading from one park to another or from the center of a residential district to an outlying park. The study of the environs of Boston showed that the five distinctive features of the landscape were the three rivers, Neponset, Mystic, and Charles, and the two highlands—the Middlesex Fels and the Blue Hills. These five distinctive features have been preserved almost entirely. Their complete acquisition for the benefit of the people in general will be secured by the money which has been given to the Commission, of which I will speak later.

From the State House, the Boston Commons and Public Gardens lead to Commonwealth Avenue, which in turn leads to the Charles River, on both sides of which park strips have been secured running westerly to this point, eleven miles from the State House. A parkway leads back by the Charles River to the Harvard Bridge, and another parkway leads to this point, also eleven miles from the State House, in a southwesterly direction, connecting the Charles River and the Blue Hill Reservations. The latter reservation is the largest park in the country. Within its confines not only could the entire area of Fairmount Park be placed, but in addition, all of the parks and squares that Philadelphia possesses. Fairmount Park is no longer the largest park in the country: indeed, in the Middlesex Fels Reservation of Boston it has a rival, as that reservation also has 3000 acres. From the Blue Hills Reservation a parkway leads easterly to the water front along the bay and thence connects with the delta of the Neponset River, along which, park reservations have been secured. These southerly divisions of the system are connected by the Blue Hills Parkway with Franklin Park, and the Arnold Arboretum. The former park is connected with the Harvard Bridge by the Back Bay Fens, a parkway which is becoming more and more famous.

Running northeasterly from Franklin Park is Columbia Road, a parkway recently opened, which leads to the Strandway and the latter to Marine Park and Fort Independence, well out in the bay.

You will observe that the northern portion of this system, as shown on the map, is likewise connected into a series of parks and parkways, ocean beaches, and river drives. A connection between the northern and southern portions of the system has not yet been made, but it will probably be constructed on this general line, cutting through the heart of Somerville and Cambridge in much the same way that the Fairmount Park Parkway will cut through the built-up portions of our own city. The Boston proposal is less fortunate than the Fairmount Park Parkway proposal, because it will not be so much of a diagonal, and therefore not so much of a cut-off. Running eastwardly from the Harvard Bridge along the southern bank of the Charles River, a river drive will be constructed to connect with the Charles Bank Playground, which lies north of the Capitol. This proposal suggests our own opportunities along the Schuylkill River bank, upon which Mr. Leslie W. Miller will address you. About 7000 acres of the parks surrounding Boston are owned by different municipalities, and the majority of them were in existence when the Boston Metropolitan Park Commission was appointed in 1893. With the additions that the Metropolitan Park Commission has acquired for Boston there are now within eleven miles of the State House over 15,000 acres of parks and 15 miles of parkways actually constructed, and 10 miles more for which the land has been secured. This has been constructed at a cost of $11,196,840, expended by this one commission. Within 11 miles of the City Hall of Philadelphia there are 200,000 more people than within eleven miles of the State House at Boston, and yet for this considerably greater population Philadelphia has so far provided only 4061 acres of park land and but one-half mile of parkway actually constructed.

The city of Buffalo offers a good example of this movement. Its system is almost complete. Buffalo has less than one-third of Philadelphia's population, but it has more than twice as many of the small triangular grass plots, less than one acre in extent, which add so much to a city's attractiveness. Philadelphia has only 12 of them as compared with Buffalo's 26 and Washington's 275, the latter due to its admirable city plan. For a city of its size, Buffalo has an admirable plan, because the streets radiate from its center, marked by a small park, in all directions, excepting west, in which


MAP OF THE CITY
OF
NEW YORK
SHOWING
EXISTING PARK SYSTEM.
SCALE
HUDSON RIVER
EAST RIVER
HARLEM RIVER
BATTERY PARK
CITY HALL PARK
BROADWAY
WASHINGTON SQ.
UNION SQ.
MADISON SQ.
TOMPKINS SQ.
BRYANT SQUARE
DE WITT CLINTON PARK
SEVENTH AVE
SIXTH AVE
FIFTH AVE
PARK AVE
THIRD AVE
CENTRAL PARK
RIVERSIDE PARK
MORNING SIDE PARK
ST. NICHOLAS PARK
COLONIAL PARK
MT. MORRIS PARK
FORT WASHINGTON PARK
HIGH BRIDGE PARK
HARLEM RIVER SPEEDWAY
GRAND BOULEVARD AND CONCOURSE
CLAREMONT PARK
CROTONA PARK
ST. MARY'S PARK
BRONX PARK
MOSHOLU PARKWAY
CORTLANDT PARK
BRONX AND PELHAM PARKWAY
PELHAM BAY PARK

direction lies Lake Erie. There can be but little doubt that the essential beauty of a city is dependent to a great extent, one may say fundamentally, upon its city plan. This is being recognized in Germany, where books have been written upon the subject and where a monthly magazine, devoted to the discussion chiefly of the city plans of outlying sections of German towns, has recently been started.

The park systems that have been secured in American cities have in a measure tended to break up the monotony of the usual city plan, as is well illustrated in Omaha. While Omaha, like a number of American cities, has copied Philadelphia in its very unfortunate cast-iron gridiron plan, yet the park system brings a certain amount of attractive irregularity into its plan, particularly in the southern portion.

You will, of course, observe, from the accompanying maps, that the idea of co-ordinated park systems is being carried out. Green color uniformly indicates existing park systems, and brown, proposed. The map of New York shows that, while the southern end of Manhatten Island, which we know so well, can boast of but few parks, the northern portion of the city—namely, the Borough of Bronx—has secured a connected system. Riverside Drive is being pushed northward to connect with Fort Washington Park, and it is likely that in 1909 the latter will be connected by a memorial bridge to Heinrich Hudson, across the Spuyten Duyvil Creek, with a wooded promontory at the extreme northern end of the city. The Cortlandt and Bronx Parks are connected with each other by the Mosholu Parkway, which is 400 feet wide throughout its one mile of length, and the latter with Pelham Park by a parkway two miles in length and 400 feet in width.

Brooklyn has a system, not a very good one, but one which is connected to some extent with its central axis, Prospect Park.

Staten Island rejoices in only two acres of parkland, but the Staten Island Chamber of Commerce has awakened to its opportunities, and a report has recently been issued which urges the acquisition of one-tenth of the acreage of the island for park purposes. This area of about 4000 acres will be distributed in a considerable number of large and small parks connected by parkways. In addition, the New York business men who live in Essex and Hudson Counties, N. J., have begun movements for park systems and the Essex County system has grown from 26 acres ten years ago to

3500 acres and 3 miles of parkways, the beginning of an extensive system of connecting links. The Hudson County Park Commission has been appointed in the last six months, and I have received a number of requests from them for information for their first report, which will soon be out.

The city of Providence has secured the passage of an act of the Legislature and its approval by the Governor, which directs the appointment of a commission to consider the park possibilities of Providence and the neighboring cities and towns, the commission to report in January, 1905.

Harrisburg is not to be outdone in this matter, and is definitely at work securing a complete park system, which was recommended by Mr. Warren H. Manning in a report two years ago. Public-spirited citizens have within the last two or three weeks taken the Mayor and the Councilmen to Boston, where the park system was investigated at considerable length. Much enthusiasm was created by the trip.

The Municipal Art Society of Baltimore has recently published an exceedingly valuable report by the Olmsted Brothers upon park development for that city. While the fire will doubtless cause the postponement of the carrying out of the project in the immediate future, such postponement is not likely to be for more than two or three years. The proposals of the Olmsted Brothers will give Baltimore an addition of 24 small parks covering over 200 acres, great outlying reservations each several thousand acres in extent, one-half of which approximately will be water surface, and 56 miles of parkway connecting links.

The city of Minneapolis has secured a fairly complete system, and has made admirable use of its water front opportunities, whether they be the Mississippi River banks or the shores of the lakes that lie inland.

St. Paul has been at work on a park scheme, and its Park Commission has approved a plan for three parkways that will lead from three different directions to the new State Capitol. These three parkways will cut existing buildings in much the same way that the Fairmount Park Parkway does. While we in Philadelphia think we are doing a good deal in having furnished $2,000,000 to begin the Fairmount Park Parkway, St. Paul has quietly planned for three such parkways.

The map of Cleveland shows that it has secured about one-fourth


MAP OF
CLEVELAND
SHOWING
EXISTING AND PROPOSED PARKS.
SCALE
N
LAKE
ERIE
CLIFTON
BOULEVARD
EDGE WATER PARK
SCENIC PARK
GORDON PARK
WADE PARK
WOODLAND HILL
PARK
VALLEY PARK
WASHINGTON
PARK
BROOKSIDE
PARK
GARFIELD
PARK

of the surrounding parkway, which will ultimately connect these parks in the manner shown upon the map. In addition it has actually begun the carrying out of a group plan. This plan contemplates the creation of a mall with a United States Post Office, now in course of erection, upon one end, and next to it a public library, and at the lake end a monumental Union Station. At the right and left as one looks from the station, a Court House and a City Hall are proposed, the latter fronting on an esplanade, the ground of which is already owned by the city, will be at right angles to the mall. This entire scheme is being carried out. I have a recent letter from one of the Commission as follows:

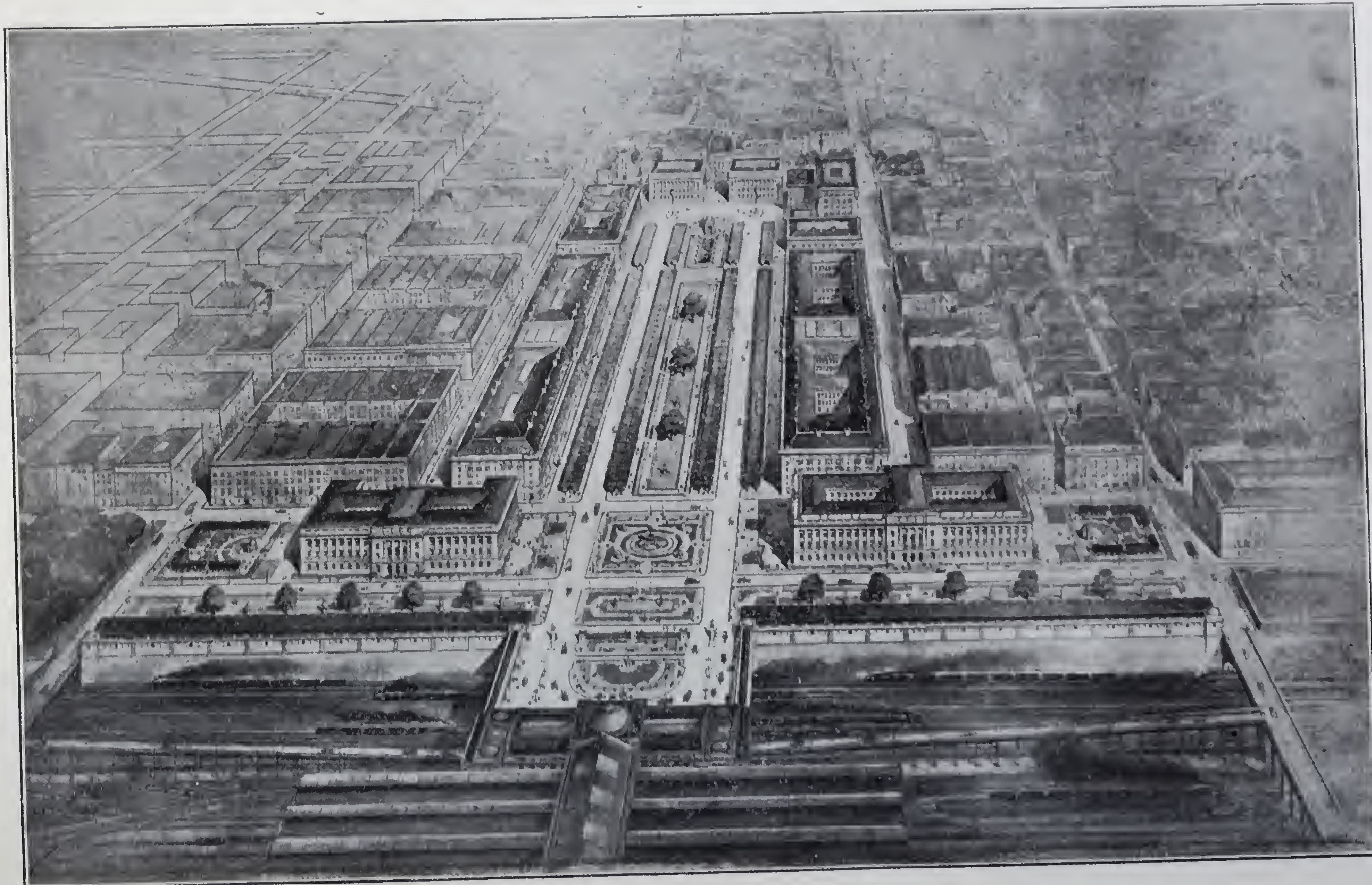
"Matters are progressing well in Cleveland. The present condition is this: The sites for the City Hall and the County Court House—that is to say, the two buildings facing the lake—are purchased. Architects have been selected for these two buildings, and the plans are progressing. The Post Office is well under way, and several parcels of ground in the mall have already been bought by the city and new ground is constantly being acquired. The Chamber of Commerce, at a meeting held September 27, 1904, enthusiastically approved the entire scheme, and I think I may say that the progress is most gratifying."

This plan it is estimated will cost about $15,000,000. Cleveland has about one-third of Philadelphia's population. If, then, Philadelphia proposes to spend as much per capita upon its central improvement, the Fairmount Park Parkway, as Cleveland is now doing upon its central improvement, Philadelphia will spend $45,000,000.

I may say, in this connection, that San Francisco, with less than one-third of our population, has recently voted $18,000,000 for improvements of various kinds, $4,000,000 of which look to the "City Beautiful," by the construction of parks and parkway connecting links, and public buildings. If Philadelphia had created as great a loan, instead of our recent $16,000,000 loan, we would have voted $61,000,000 for this purpose.

St. Louis, encouraged by the example of Cleveland, has recently received the report of the Kingshighway Commission upon a plan for connecting a number of existing parks by the Kingshighway; and also a report of another commission on a group plan. These two plans will cost in the neighborhood of $6,000,000.

Hartford, Connecticut, has largely acquired the parks of a com-



Cleveland Group Plan, Now Being Carried Out.


MAP
OF THE
DISTRICT OF COLUMBIA
SHOWING
EXISTING AND PROPOSED PARK SYSTEM
SCALE
ROCK CREEK PARK
SOLDIERS HOME
MUNICIPAL HOSPITAL
NEW RESERVOIR
ZOOLOGICAL PARK
ARMESLEIGH PARK
U.S. NAVAL OBSERVATORY
CONDUIT ROAD
RESERVOIR
POTOMAC
RIVER
ANALOSTAN IS.
POTOMAC PARK
POTOMAC RIVER
ARLINGTON RESERVATION
ANACOSTIA
LAKE
CITY FARM
ANACOSTIA RIVER
GOV'T HOSPITAL FOR THE INSANE
N

plete park system and has likewise just begun the creation of a civic center.

The greatest of these park and parkway plans is for the Federal capital. The Senate Commission, appointed in 1901, presented a plan for the development of a mall. Since that time, I am glad to say, no less than nine buildings have been authorized in accordance with the plan referred to; they are the House of Representatives Building, the Senate Building, the Agricultural Department Building, the National Museum, the Hall of Records, the Municipal Building, the Union Station, the Washington University Building, and the building of the Daughters of the Revolution. In addition, the Commission, which is composed of the most eminent architects, sculptors, and landscape architects in the country, have proposed this outer park plan, which will give Washington 8000 acres of parks and 63 miles of parkway connecting links.* You will observe that the Rock Creek Park at one corner will be connected with the Anacostia River Park, and that, in addition to the parkways that lie nearer the city, there will be this outer link, which will connect the 14 forts that were built during the Civil War for the protection of Washington.

I have by no means exhausted the list of American cities that are acquiring park systems, nor will I when I have mentioned such cities as Seattle, Toledo, Louisville (Kentucky), Indianapolis, Springfield (Illinois), and Springfield (Massachusetts). The idea is being adopted throughout the country.

In order to raise Philadelphia from her lowly position to one of eminence, we have formed the alliance of 41 organizations for the acquisition of a comprehensive park system for Philadelphia, and now appeal to a club composed of engineers to make it 42. While the work of the Allied Organizations must be largely of the character of agitation, yet the carrying out of its recommendations will require a technical consideration, and therefore the recommendation of the Alliance should be technical in character. It seems, therefore, that no body of men can give more valuable assistance in this movement for Philadelphia than the Engineers' Club.

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* Note.—The dark green on this map indicates grounds that are open to the use of the public, although not officially denominated "parks."

THE IMPROVEMENT OF THE SCHUYLKILL WATER FRONT.

LESLIE W. MILLER.

The speaker who has preceded me has called your attention to the things that the other cities are doing in the way of outer parks and to the possibilities, more or less inviting and ready at our command, around our own home. The task has been assigned to me of speaking for that phase of nearly every city's topography, that feature of nearly every great city in the world, which presents, if properly accepted, a natural parkway, a natural beauty, which if not accepted, but neglected, allowed to give way as things do give way in a great city, if they are not taken care of, becomes the opposite of all that is beautiful, all that is attractive, all that is pleasing in the outward expression of that city's life. It is the water front. I maintain that there is no surer, safer sign of a city's health or rightness of thinking or living than its treatment of its water front. I believe as heartily as any of the gentlemen have or can believe, in the new parkway, in the system of parkways through the city's built-up portions and around the beautiful valleys which surround the city; but I insist that it is our duty to remember almost first the actual parkway, the potential parkway which we have at our doors, which to take care of would mean beauty, and strength, and health for everything concerned with municipal life, and to neglect means the opposite of all that. Instead of being through the middle of the city something very much like a slum, our Schuylkill ought to be the most charming spot we have. It is a business of every such organization as this, which stands for anything in the way of united effort for the promotion of good work in our midst; what else do we form for but to help, to come together and help? I certainly think it is the duty of every organization to help to promote the public sentiment which has already been alluded to as the natural force we have to bring better things about. Now, I am not going to deprive Philadelphia of anything. I am a proud Philadelphian. I believe in my city and I am proud of it, and I don't want to make any invidious comparisons or parade the European example in disparagement of our own country; nothing of the kind. I simply want to call attention to what we ought to do with our

The Treatment of the Banks of the Saone River at Lyons, France.

The Banks of the Schuylkill River can Readily be Embellished as the Saone has been at Lyons. While the Railroad should be Hidden, it Need Not be Removed.

great waterway, and to show what every other city in the world that has progressed a little further than we have has done, and what I am sure we are going to do. I am not finding any fault because we have not done it, but I am only pointing out what everybody else has had to do to simply get in my little plea for the prompt and cheerful doing of what is before us. It is our duty to remember and to remind everybody else, the combined sentiment of whose minds makes up that great force which we call public opinion, which can bring anything to pass which it wants to bring to pass. We ought not to lose any more time, and incidentally ought not to waste any more money.

Comparisons are not odious if made in the spirit of trying to learn. They are not odious if we learn the lessons which they have to teach.

The enhancement of real estate values in the neighborhood of centrally located park improvements can be depended upon to repay the cost of such improvements in a very few years. In the report of the New York Park Association for 1882, for example, the following statement occurs:

"The amount collected (in taxes) in twenty-five years on the property of the three wards named (the wards contiguous to Central Park) over and above the ordinary increase in the tax value of the real estate in the rest of the city was $65,000,000 or about $21,000,000 more than the aggregate expense attending and following the establishment of the park up to the present year. Regarding the whole transaction in the light of a real estate speculation alone the city has $21,000,000 in cash over and above the outlay, and acquired in addition thereto land valued at $200,000,000." The testimony to the same effect from Boston and Chicago, where park improvements have been carried out on the most generous scale, is quite as convincing. Even if Philadelphia is indifferent to the claims of such improvements to the river on any other grounds, but was simply desirous of making some money, there can be no reasonable doubt that this is the way to do it. The experience of other cities is conclusive evidence that with a beautiful parkway skirting the river the neighborhood would soon become the finest residential section of the city instead of the unspeakable eyesore which it is at present.

DISCUSSION.

George S. Webster.—We have for many years been in the habit of boasting in this city of our great and beautiful park. To-day we have fallen far behind

in area, and in fact, our parks are not large enough to meet the requirements on general holiday occasions; so that in many cases our citizens are compelled to trespass on private property for the recreation ground the city does not furnish. It would therefore seem proper at this time that we should follow the example of other American cities and arrange for the extension of our Park System.

There exists within the limits of the city a number of beautiful valleys, splendidly adapted by nature for parks. They are susceptible of park development, and the cost of acquiring them, laying out the necessary drives, and otherwise improving them would not, in many cases, entail as large an expenditure upon the city as the opening of streets across and through them, with consequent heavy land damages to be paid out of the city treasury.

The valleys of Cobb's, Pennypack, and Poquessing Creeks, each possesses much natural attractiveness, with alternating reaches of meadow and woodlands hemmed in by hills.

In order to secure for Philadelphia a comprehensive system of parks the public must be educated to the necessity, so that legislation may be obtained. With this object in view a number of scientific, educational, and art societies and business and improvement associations of the city have joined together under the title of the Allied Organizations. The purpose is to issue, from time to time, illustrated publications upon park development, and thus increase the sentiment in favor of the acquisition of additional park area and the construction of connecting parkways.

COMMUNICATED DISCUSSION.

William Copeland Furber.—Philadelphia has been a commonplace city so long that we have become used to the commonplace and it no longer causes us any dissatisfaction. The reason why we have no boulevards is because we have never had the first one, and, trite as this statement may seem, it is needless to say that, had the city once been beautified by a properly laid out boulevard, the example would have been followed and the city to-day would be a better and more interesting place to dwell in. As it is, the suburbs of the city are being developed at the expense of the city, and improvements that might otherwise be made in the city are made in the country, because the city furnishes no adequate setting for them.

Philadelphia has suffered from the ubiquity of the operative builder. In all parts of the city the work of his commercial mind is seen, row after row, block after block of uninteresting houses are seen, and the wholesale construction of ready-made houses has become so much the vogue that we look for nothing else. This state of affairs has smothered all artistic impulses in the older generation, and left nothing for the instinctive love of beauty in the younger generation to feed on; consequently this sense is not developed and does not become strong enough to cry out for a change.

Ruskin says of the building of dwelling houses:

"I would have then, our ordinary dwelling houses, built to last and built to be lovely; as rich and full of pleasantness as may be, within and without . . . with such differences as might suit and express each man's character and occupation and partly his history."

If this rule should be applied to Philadelphia, with its long vistas of machine-made house fronts, it would indicate that the greater part of the inhabitants of the city had the same character and occupation, and these characters and occupations exceedingly uninteresting ones; and yet it does follow to a certain extent that this is true, or the individuality of the citizen could not be so easily and effectually repressed as it is in the matter of dwellings, politics, and city management, and back of all this there lies a reason: A public which unprotestingly accepts ready-made houses, also accepts ready-made politics and ready-made thought, or, in brief, accepts what is given it without thought or question. From these evidences it is apparent that the great body of the people is not initiative and is therefore doubtless composed of employees who are accustomed to taking orders. Indeed, it is hard to account for the servility and the contentedness of the great mass of the people of Philadelphia on any other hypothesis. Under such conditions as these, it is necessary to set an example and do some educational work.

These gentlemen who have shown us by comparison how the banks of the Schuylkill River might be treated, as rivers are treated in European cities, and who have shown the feasibility of pre-empting the creek valleys for an outlying park system, are doing this necessary educational work, and it is to be hoped that they will keep up heart, and in season and out of season will show the people wherein they are so lacking, and that the truth will be finally forced home to them.

In democratic countries the people are theoretically sovereigns and to them belongs the responsibility. If, by reason of shirking their duties, their powers are usurped by the party bosses, they are none the less to blame. In monarchies the rulers often take the initiative and construct public works and improvements on a large scale, but in governments by the people the recognition for the necessity of such improvements must first arise from the enlightened intelligence of the citizens.

The absurdity of extending the gridiron system of streets, with its lack of conformity to the topographical conditions of the ground and its necessary destruction of the natural woodlands and parks is so monstrous that it calls for the instant cessation of this mechanical and unsuitable system.

Let us send our District Surveyors to schools where city planning is taught as a fine art and let them learn that there is a science of beauty as well as a science of grades and levels; then we may hope for better things.

What we all need as citizens is a broader knowledge of civic betterment and a higher æsthetic appreciation of municipal possibilities; then the banks of the Schuylkill may be redeemed from their present squalor and be converted to architectural decency, and our streets and parkways be so treated that this urban life of ours may be more of a delight.

ELECTRIC DRIVE.

E. L. WALKER.

Read November 19, 1904.

THE economic operation of any given shop is always dependent on a number of considerations, each one of which must claim its proper amount of attention.

The establishment of electric drive, or of a system of cranes, or the paying of men by the piece-work plan, or the adoption of any one of a dozen modern methods, will not in itself raise the shop to its highest efficiency. That state can only be attained by a careful regard being given to all sides of the varied and complicated problems which relate to the operation and management, and which first arise with the planning and designing of the shop buildings; however, even after a given shop has been in successful operation for a number of years, it is often quite possible to increase its efficiency, and sometimes to a large extent, by the adoption of one or more of the more modern methods, or by a more careful attention to some detail of the present practice. Often by simply changing the belts on a machine from single to double thickness an increase in the roughing cuts may be made possible which will greatly facilitate the work. Often, too, by the adoption of a wider finishing cut a great deal of time can be saved.

If it takes an hour to run the finishing cut across a piece of work on the planer at $\frac{1}{16}$-inch feed, it will take one-half an hour at a $\frac{1}{8}$-inch speed, thus saving thirty minutes. Another increase of $\frac{1}{16}$ inch in the feed, making the total $\frac{3}{16}$ of an inch, will allow of finishing the piece in twenty minutes; thus saving ten minutes more. The first increase of $\frac{1}{16}$ inch in the feed saved thirty minutes, while the next increase of the same amount saved only one-third as much, or ten minutes.

The following table shows this calculation carried on to a feed of $\frac{1}{2}$ inch, which is not at all excessive, as often 1-inch feeds are taken on comparatively smooth work with good results.

It will be seen from reference to the last column that the first increase of $\frac{1}{16}$ of an inch in the feed saved more time than all the other increases added, up to a total feed of $\frac{1}{2}$ inch, in the first case

thirty minutes being saved and in the second a further saving of 22.5 minutes being attained. Putting it in another way, we may say that, given a certain job requiring one hour to complete the cut at $\frac{1}{16}$-inch feed, as much saving may be made by increasing the feed $\frac{1}{32}$ of an inch as will be further gained by an additional increase of $\frac{3}{32}$ of an inch, making a total feed of $\frac{3}{16}$ of an inch. The foregoing table is shown graphically by the following curves (Fig. 1). These curves are plotted between feeds expressed in sixteenths of an inch, and time expressed in minutes. Curve 1 shows the time required to do the piece, 2, the time saved, and 3 the time saved by each increase in feed.

FINISHING FEED	TIME REQUIRED TO DO PIECE	TOTAL TIME SAVED.	TIME SAVED BY EACH INCREASE IN FEED OF $\frac{1}{16}''$
$\frac{1}{16}$	60	—	—
$\frac{2}{16}$	30	30	3c
$\frac{3}{16}$	20	40	10
$\frac{4}{16}$	15	45	5
$\frac{5}{16}$	12	48	3
$\frac{6}{16}$	10	50	2
$\frac{7}{16}$	8·6	51.4	1.4
$\frac{8}{16}$	7.5	52.5	1.1

These calculations show the advantage to be gained by very small improvements, and that given a case, any improvement in it, however small, will probably be productive of more economy than any improvement along the same line which will be made afterward. The same calculations may be made for the gain in production by deeper cuts, increased speed, or any other improvement, and the curves, if plotted, will be similar to those shown in Fig. 1.

Probably no other subject directly connected with machine tools is attracting more attention than the efforts of the builders to meet the demands being made upon them by the high-speed steels now on the market, and probably the most interesting feature of present-

day practice in electric motor building is along the same line. It is this phase of the subject I wish to take up more at length, and it may be briefly stated as a discussion of variable speed motors and the methods of applying them to machine tools.

Variable Speed Motors.—In the early application of variable speed drive the tendency on the part of the designers was to make the motor an integral part of the tool; on lathes, for example, to embody the motor in the headstock, with the armature built direct on the lathe spindle, the range of speed being accomplished by armature control or by combined armature and field control. It

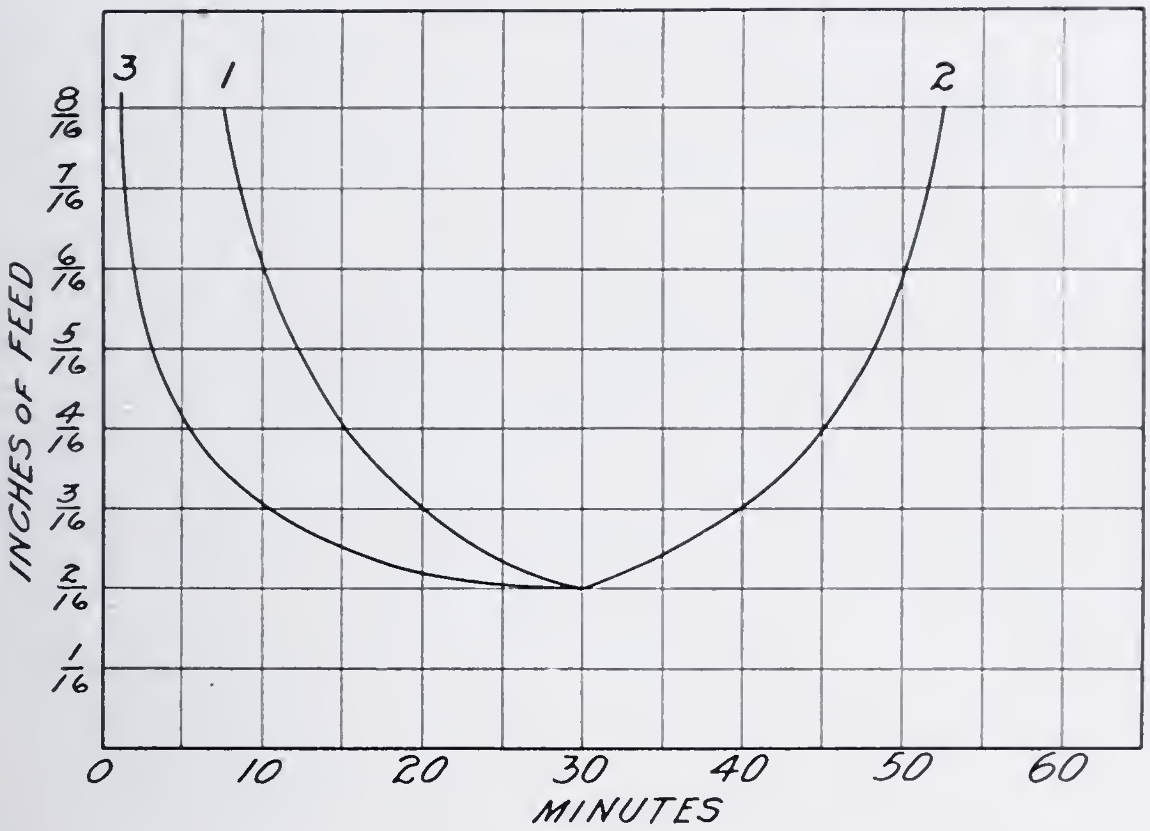


Fig. 1.

required some time for different manufacturers and users experimenting along this line to find out that this was an impractical solution of direct connection. This brought about the consideration of the multivoltage system and the double commutator systems, which are more or less complicated in themselves and at the same time necessitate a very special controlling apparatus, and which, owing to the excessive first costs and cumbersomeness in operation,. are dropping out of use.

The main objection to the combined armature and field control is, of course, its lack of efficiency. The current passing through the field windings, being small, causes little loss when cut down

by a resistance in series, but that passing through the armature, being proportional to the work being done and, therefore, very heavy when the motor is working at full load, suffers a proportional loss when cut down by a resistance placed in the circuit; added to this is the annoyance of having the machine, when driven by such a motor, slacken speed at a point where the cut is either light or runs entirely out, and speed up as the tool re-enters the work sufficiently to burn the tool.

It has been urged by many motor builders that it was impossible to build a motor to give a great variety of speeds regulated entirely by field control, and that the idea itself was impracticable, owing to the supposed necessary size of the motor for a very small variation of speed.

The desirability of such a system, however, led to experiment, and to-day there are variable speed motors on the market giving a range in speeds of from 1 to 2, to 1 to 5, and in special cases 1 to 6 or 8. Probably some of the best examples of variable speed motor building are furnished by those companies which obtain their variation in speed by a system of field resistance alone, and a comparison of the operation of their motors with those of other systems brings out many points of interest to the user of motors in general.

When the one voltage system and field resistance method of control is compared with the multivoltage and double commutator systems, it shows a large advantage in that the same variation in speed is accomplished in a much smaller frame. This feature of compactness makes it possible to use the variable speed motors on work where it would not be commercially feasible to use any other system, either on account of lack of space in which to fit the motor or the high first cost where multivoltage and such systems are being considered. The variations of speed with this system are accomplished by using a much smaller form of controlling apparatus than with the other systems mentioned, and one in which the chances of trouble are reduced to a minimum. In the latter case the controlling apparatus is much more complex, and at the same time there is always the danger of the operator permitting the controller to stop between any two combinations, which allows the tool to slacken, and, when the controller is brought on to the next combination, there is danger of not only wrecking the gears, but of burning out the equipment, should the fuses fail to blow or the circuit breaker fail to throw out.

With the one-voltage system, using the field method of control exclusively, there is no time when the armature and field circuits are open; consequently the increase and decrease in speed from one step to another is continuous.

With the one-voltage system it is possible to install an equipment in any factory where at present they have direct current without the additional cost of special wiring. This method, therefore, lends itself much more advantageously to the general class of machine-shop practice, as it is possible to connect one of the one-voltage system equipments to any direct current set of mains already installed. This item in itself is of vast importance to the purchaser of any equipment, in that it does not necessitate any delay or special arranging for installing the motor-driven apparatus.

In addition to the added first cost of special apparatus required in the power house, and the motor controllers for the double commutator, two-voltage system, and the multivoltage system, the additional wiring is a large item of expense. The two voltage system requires three wires and the multivoltage at least four wires to each motor, and these wires have to be of larger size than those required in the single-voltage system; so that twice as much copper is required in the first case and three times as much in the second as is required when the one-voltage system is used. This, together with other necessary material and the extra labor required, makes an item worthy of careful consideration.

One of the most important features of this system of control is the fact that it gives the full rated horse-power throughout the range of speeds. There is no other system which can do this, both the multivoltage and the armature-control systems falling off in horse-power as the speed decreases. This performance is extremely objectionable for machine tool drive, in that it is almost invariably the case that the maximum horse-power is required at the slowest speeds at which the tool is driven, and in the use of any other control than this it is necessary, in order to get sufficient power at slow speeds, to equip the machines with a motor of abnormal size and horse-power at the high speeds.

Of course, the ideal condition would be to get a constant torque, which would necessitate a larger horse-power at the higher speeds; nevertheless, it is a step in the right direction to get even a constant horse-power at all speeds.

The bases of the belted motors have a belt-adjusting device by

which the belt can be tightened by a few turns of the adjusting screw. In the larger sizes the pole pieces can be removed complete, thus allowing of light repairs to the armature without removing it.

Motors of this class are sometimes provided with a back gear-shaft, which reduces the number of revolutions to the desired amount without the use of a counter-shaft. This back gear has bearings on the motor frame. These motors may be operated either on the floor, wall, or ceiling without any change, except to turn the oiling apparatus over into proper position.

For ordinary machine tools the manufacturers recommend a motor of speed variation of 1 to 2, where it can be used, as it requires a much simpler controlling mechanism than does a higher ratio.

For lathe work a 1 to 2 variation of speed in the motor, taken in connection with one change of speed in the gears, will give a speed variation at the tool of 4 to 1. Gear ratios can be worked out so that, when the speed has been increased through the range of the motor, another driving gear can be thrown in; so that with the motor running at its slowest speed the tool will have the same cutting velocity as it had just previous to the change; now, the motor may be speeded up through its range and the same process of change of gear accomplished as before, and so on through the entire range of the machine tool, thus giving every possible cutting speed from the slowest to the fastest without any gaps. This arrangement is low in first cost and efficient and convenient in operation.

The actual arrangement of the necessary change of gears has been worked out in slightly different ways by the various manufacturers, some using slip gears, others obtaining the change by means of friction clutches. The friction clutch scheme is very desirable, in that the entire range of speed can be given the tool without the stopping of the motor.

This sort of arrangement is shown in Fig. 2, the Gisholt lathe driven by a variable speed motor. While the builders of this motor recommend a speed variation of 2 to 1 in the usual cases of lathes, boring mills, and machinery of that class, yet they are inclined to believe that such tools as shapers, planers, and milling machines should be equipped with motors giving a speed variation of 4 to 1.

The controlling apparatus for a lathe equipment consists of either a drum type or slate front controller, mounted at A and attached to a splined rod, B, by the sprocket chain, C. This rod is operated, through a set of miter gears, by a lever attached to the apron of the

lathe at D. The operator has, therefore, right at his tool carriage, a lever with which he can start, stop, vary the speed, or if necessary reverse the direction of rotation of his lathe, and is therefore in a position to have absolute and easy control of his machine at all times. For surfacing machines the controller can be mounted on any convenient part of the machine, and is then well within the reach of the operator. A controller is furnished for this class of work which is operated by two levers: one starting or stopping the machine and the other varying the speed. This apparatus is, however, so arranged that, should the machine be stopped by the operator, or by the stoppage of the current, or due to an overload opening the circuit breaker, the starting lever is thrown back to the off position, and in returning to that position the field-control lever is brought back to full field. It is, therefore, impossible on any of these controllers to start the machine upon an extremely weak field. All these controllers are equipped with the necessary armature resistance for starting up the machine; but immediately after this is done all this resistance is cut out and the speed variation obtained by field control alone.

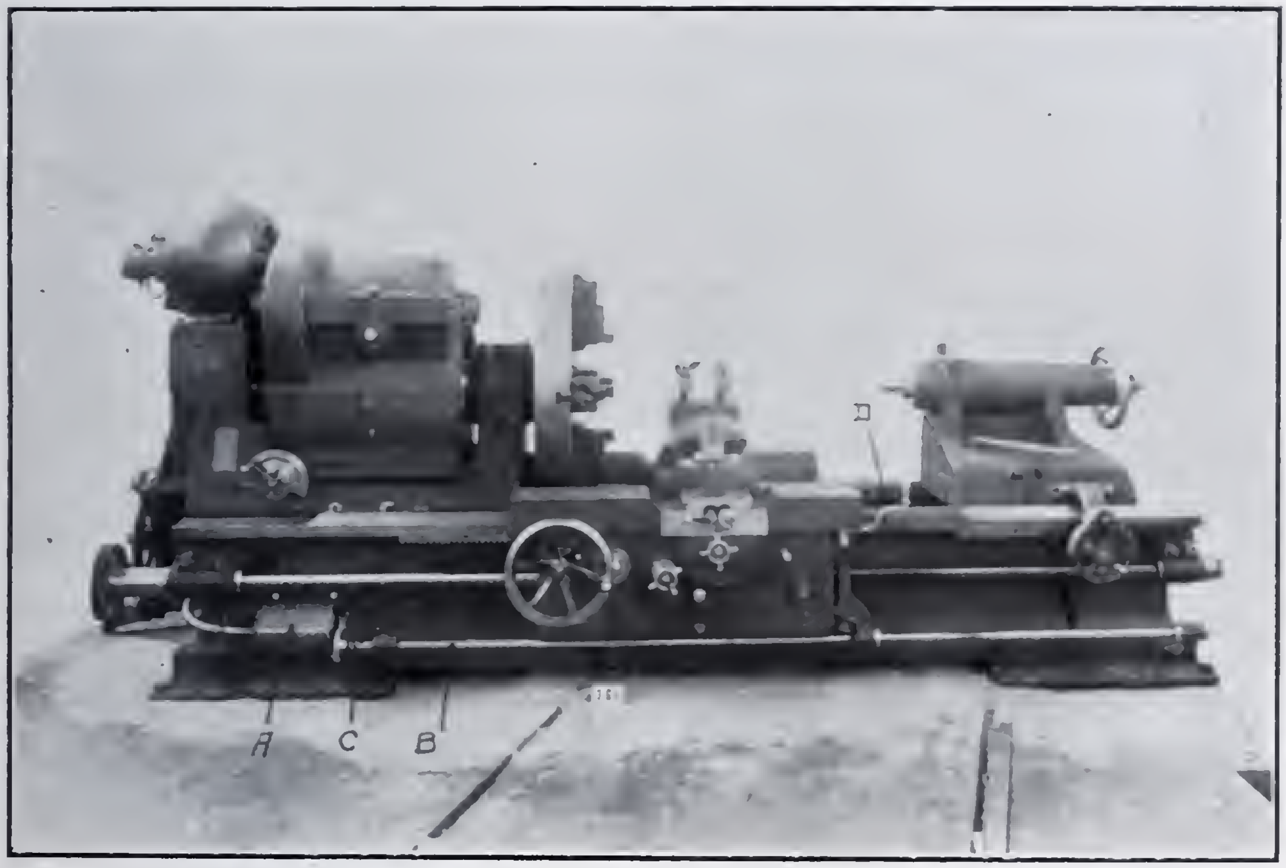


Fig. 2.

Most of these motors are rated on the basis of their operating in one direction, and most machine tool builders at the present time

are designing their tools so as to use a motor of one direction of rotation, as it enables them to use a smaller frame for a given capacity, and, in fact, is more desirable from all standpoints.

The manufacturers of these motors sum up the claims for their system of drive and motors as follows:

1. The one-voltage system is used.

2. They accomplish the entire range of speed by the use of field resistance alone, excepting that in cases where an extraordinarily wide range of speed is required they use one change of gears in combination with the variable speed motors.

3. They are able at the present time to get a greater range of speed in a corresponding size of frame than any of their competitors; in fact, it is claimed by some to be impossible to get as great a range of speed as 5 to 1 in the motor itself by field control. Motors are built on this system which run as low as 330 revolutions per minute under full load.

4. They eliminate the complex control and expensive controlling apparatus and wiring necessary in the double-commutator and multi-voltage systems.

5. Their equipment is applicable to any two-wire direct-current system already in use.

6. They can give the full, rated horse-power of the motor through the entire range of speed, their system being the only one which can do this, and they guarantee a regulation inside of eight per cent. from no load to full load on all controller points.

7. Their system is claimed to be the most efficient on the market.

Direct Planer Drive by Controller System.—The Electric Controller and Supply Company, of Cleveland, Ohio, are introducing a special design of controller for planer work which allows of connecting any variable speed motor directly to the cross-shaft of the planer by means of a gear and pinion, the speed regulation and the reversing being accomplished by their system of control.

Fig. 3 shows a Pond planer with their attachments. A is the motor geared to the cross-shaft from which the pulleys have been removed. B is the reversing controller box which is operated by the lugs on the planer table, similarly to the ordinary operation of reversing. C are the controllers which cut down the field resistance and therefore regulate the speed of the table, one for the forward stroke, and one for the backward. These can be set, by turning the handles shown on top, to give any desired cutting speed and return

speeds of greater velocity. A switch-board and resistance boxes are shown at D. The switches, arranged in a row at the top, are automatic and so connected in the circuit that upon reversal the motor is brought to rest by utilizing its own counter electromotive force as a brake, so to speak, and the current in the other direction is only admitted to the motor when nearly at rest and is gradually increased by the automatic switches.

The principle upon which this is based is that a motor when running is also acting as a dynamo, it being of exactly the same theo-

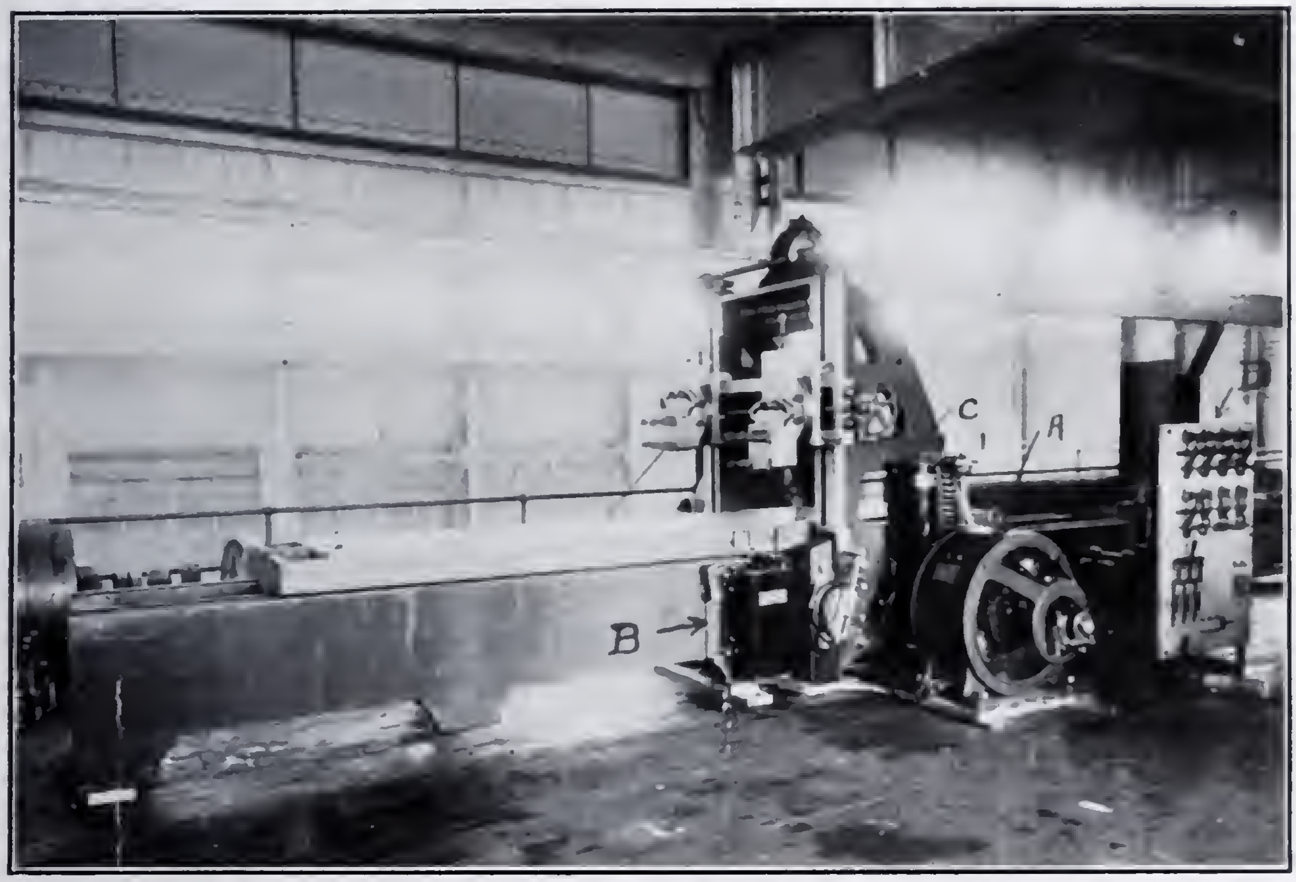


Fig. 3.

retical construction as a dynamo and differing only in the matter of details, and is producing an electromotive force equal and opposite to that of the line supplying current to it. In this case, as soon as the current which operates the motor in one direction is cut-off, a switch is thrown in, which turns the current; the motor tends to generate into a resistance box. This quickly stops the motor, as its only supply of energy, after the line current has been cut off, is the kinetic energy of the rapidly revolving armature; then the current is let into the motor in the opposite direction as rapidly as the motor will speed up. The reversals are very gradual, but any desired cut-

ting speed can be obtained up to 70 feet per minute, and the commutation of the motor is absolutely sparkless.

A disadvantage to the system is, however, that the four automatic switches must operate every time the motor reverses, and, even though they can be given large bearing surfaces and provided with carbon contact points, these are things to be avoided if possible, though the Electric Controller and Supply Company claim that the objection is not serious and that the advantage to be gained far overbalances it.

Mechanical Speed-changing Device.—The range of variation in speed which can be obtained through the variable speed motor in many

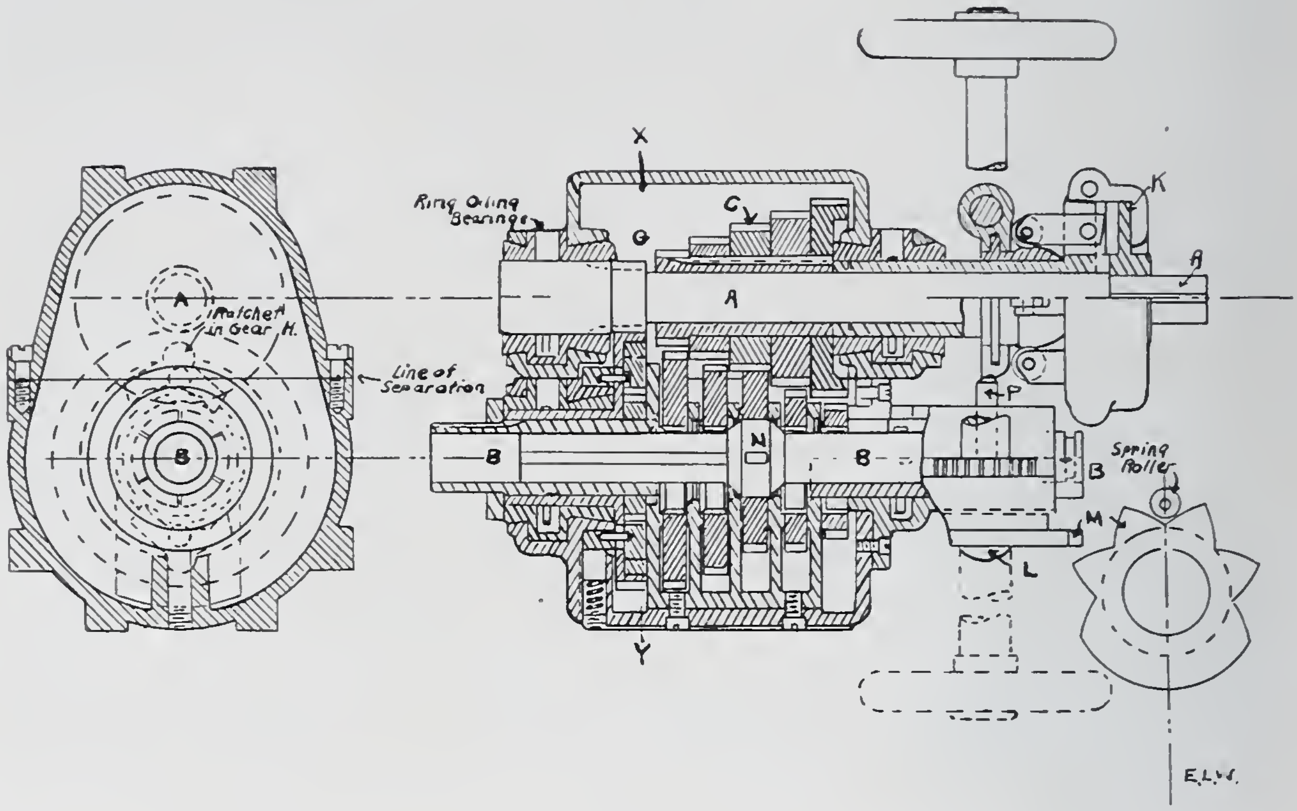


Fig. 4.

cases must be augmented by mechanical means in order to give the machine tool a wider range for varied classes of work; then too, a motor giving a variation in speed of 2 to 1, working in connection with a suitable mechanical speed-changing device, will be cheaper and more economical, due to the simpler controller required, than will a motor of high ratio of speed changes, with its more complicated controller.

The National Machine Tool Company, of Cincinnati, Ohio, have solved this problem very nicely and furnished the connecting link between the variable speed motor and the machine tool. Fig. 4 shows two sections of this speed changer. The power is delivered

to the box through the shaft, A. The pinion G is cut on the shaft, and the gear cone C, runs loosely on it. G meshes with the gear H, on the lower shaft, and thus furnishes the slowest speed to the machine. This gear H carries pawls which automatically drop into the ratchet wheel, cut on the shaft B, whenever the pawls and the ratchet are going at the same velocity regardless of direction; this, then, will be the natural speed and method of operation of the box, and when a change is made from one speed to another it will always automatically return to this condition while the change is being arranged. In order to get a higher speed the shaft B is slid along through its bearings by means of a rack and gear, controlled by the hand-wheel, till the enlargement N picks up the proper loose gear and forces it into mesh with the cone of gears C. This enlargement N, is provided with keys which fit into the seats cut in the bores of the loose gears. The clutch K is then thrown in by the lever L, and the pawls on gear H automatically fly out as shaft B speeds up in accord with the new arrangement.

Some of the advantages of this arrangement are:

1. It is impossible to operate the clutch unless the gears are properly meshed.

2. The casing allows of running the whole in an oil bath.

3. It may be so designed as to give any ratios and ranges of speed.

4. The loose gears set in chairs and are inoperative when not transmitting the power.

5. Neither the motor nor the machine has to be stopped to change speed, and yet the change is made without the gears selected carrying any load until properly meshed.

Conclusions in Regard to Variable Speed Drive.—A speed-changing mechanism properly designed to give speeds in the ratios of 1 to 2, to 4 to 8, etc., taken in connection with a variable speed motor with a range of 1 to 2, will give every speed between the lowest and highest range.

The application of this combination to an old lathe or other machine would be extremely simple. In the case of a lathe, for example, an annular gear could be shrunk on one of the cones and the end of the shaft fitted with a pinion to mesh with the gear. The variable speed motor could be geared to the shaft and the whole apparatus so arranged as to be carried by the headstock of the lathe.

If it is considered undesirable in any particular case to gear the motor directly to a shaft, a chain may be used, thus avoiding a belt,

which would necessarily be of extra large size to meet the main object of this arrangement: *i. e.*, to get the most out of the high-speed tools.

Special Applications of Motors.—A couple of special adaptions of motor drive are illustrated by emery grinders and vertical drills.

In the case of grinders the armature may be placed on the main shaft, which carries the wheels. These grinders perform the same class of work as the ordinary belt-driven emery wheel or buffing wheel. Their advantage lies in the fact that they are simple of design, easy to install, give a constant cutting speed when desired, and are devoid of belts.

The armatures of the motor for driving the wheels is situated on the same shaft as the wheels, being secured to it by two taper sleeves which automatically center it and at the same time allow of the shaft being readily removed. The bearings are of the self-aligning type, with large rubbing surfaces and provided with automatic oiling rings.

The motor itself has a dust-proof casing and is equipped with a starting device in the pedestal of the machine. This starting device also allows of weakening the fields of the motor and thus increasing its speed. When the emery wheels are new and of large diameter, a slower speed may be used, and when the wheels begin to wear small they may be speeded up, to maintain the same cutting speed at the face of the wheel as previously.

This type of grinder obviates the necessity of driving the emery wheels from the shafting of the floor below, and makes it possible to readily move a machine to a position of greater advantage. To these advantages may also be added those which are always derived by eliminating line shafting, belts, and pulleys.

The Sellers Pneumatic Planer Clutch.—This is a device for quickly and accurately reversing heavy planer platens, and at the same time gives some of the advantages derivable from variable speed drive by the use of a constant speed motor.

With the ordinary belt-shifting devices as commonly applied to planers there are three main objections; first, that the belts are necessarily limited as to width, on account of the difficulty encountered in shifting wide belts; second, the speed at which belts can be economically run is limited; and thirdly, that only a certain cutting speed can be attained, due to the losses in overcoming the inertia of the belt wheels at the ends of the stroke. While the shifting of a forward and return belt, alternately on to the driving pulley

does very well for the requirements of the old tempered steel tools, it does not permit of sufficient power to drive the modern high-speed steel to its limit for heavy cutting, and the slip consequent upon the speeding up of such a machine is so great that the benefits derived are much smaller than those aimed at. These objections are acknowledged by some of the planer builders in that they are equipping their planers with a double set of driving belts, one on each side, to meet the demands of high-speed tools.

The Sellers pneumatic clutch allows of as large a driving belt as is desired, thus permitting slow-belt speeds; and the clutches operated

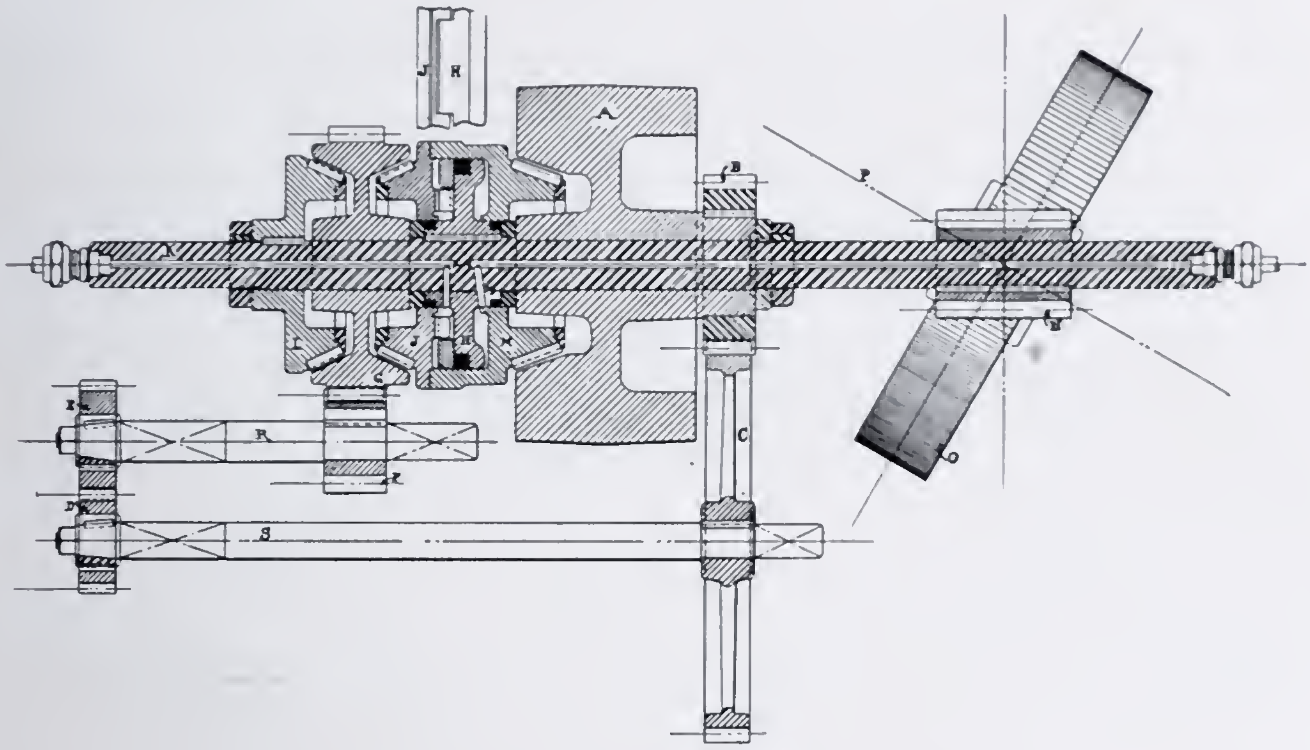


Fig. 5.

by air give such a quick reversal that the cutting and return speeds may be carried very near to the points of reversal, thus avoiding the losses due to the slowing down of the planer table before the end of the stroke is reached, and those consequent upon the very slow reversal of the old type machines when speeded up above their original design. This slow reversal detracts from the benefits derived from speeding up, as with the higher speeds the reversals grow relatively slower and slower.

Fig. 5 shows the Sellers arrangement, but not to scale. A is the driving pulley, and may be made wide enough to accommodate a belt, delivering any desired amount of power. It runs faster than the shaft, K, during the cutting stroke, and at the same speed as K, during the return. H is a piston keyed to the shaft. J and M are

clutches on either side of the piston and connected to it by projecting lugs; so that, while they may move a limited distance along the shaft in either direction, yet they always revolve with the piston, and consequently with the shaft. If air is admitted between H and M the clutch will be forced to the right and engage the driving pulley. The shaft then will revolve at the same rate as the pulley, thus furnishing the return speed to the platen. However, if air is admitted between the piston and J, the clutch will be forced to the left against the gear G, which has been running idle on the shaft up to this point. L is a clutch keyed to the shaft, and is simply to supplement the pressure exerted by J, thus giving more holding power. With the clutches J and L engaged, the belt pulley drives the shaft K through the gears B, C, D, E, F and G, thus giving the platen its forward or cutting speed.

The ratio between the gears D and E decides the cutting speed, and this may be changed by substituting gears of a different ratio. The fastest possible speed for the return stroke can be determined upon at first, and will remain constant thereafter. This arrangement can be so designed as to attach to old planers, thus allowing the purchaser its benefits, at low cost.

DISCUSSION.

Harold T. Moore.—I made a Prony-brake test recently of two different makes of motors of the single-voltage, variable-speed type, which were rated as 3 H. P. machines with a 6 to 1 speed range. The motor frames were of the size generally used on the standard 12 H. P. constant speed motors, but as they were only tested for their rated value (3 H. P.), a constant H. P. was maintained throughout the range. The minimum H. P. when the field was weakest and the speed greatest evidently determined the rating. At the slow speeds the H. P. available was greater than three, but owing to the excessively strong field necessary for so large a range, a heavy overload could not be maintained for very long at the slow speeds without a considerable heating of the field coils. On the weakest field and with normal load, a slight sparking at the commutator was observed, which was considerably increased with an overload.

The President.—In defense of the variable speed electric motor I might call attention to the fact that mechanical engineers have also failed to devise a satisfactory variable speed, constant power gear; the electrical engineer should therefore not be blamed too much. Mechanical engineers have tried for many more years to solve this difficult problem, but have not succeeded.

Mr. Walker.—The Baldwin Locomotive Works was one of the first large establishments in this country to introduce the electric drive, and to-day it would be next to impossible for them to operate without it. The shops are situated in the heart of a large city and are necessarily several stories in height. The

machines are set closely together, and the larger of these served with overhead traveling cranes. There is no method of operating these tools which allows of the crane service and at the same time proves as flexible and economical as the electric drive. In an establishment of our character the large output necessitates an easy and rapid method of handling all material which cannot be readily moved by laborers. There are about 120 power cranes installed in the works at present, the majority of which serve machine tools. This system is made possible by the employment of electrically driven tools, and though many defects may be found in the various examples of electric drive they are far outweighed by the benefits derived from the use of overhead cranes alone.

David Halstead.—In defense of the electric drive I would like to say that quite a number of the large shops in this country are using electric motors for driving machine tools. There must be some great advantage in using these motors or they would not spend the money for them.

The time saved in operating machine tools, and therefore the increase in output, can be traced to this convenient method. The turning of the handle of a controller compared with the shifting of belts to different steps of cone pulleys would result in the choice of the former. Not only is there this convenience, but one has, with the electric drive, a flexible system and a clearer head room than can be had with belt transmission. There is also a great saving in a shop where the power is transmitted through copper wire, with only the resistance of the wire to deal with, compared to the loss of friction due to the long system of belt transmission. Particularly is this so in right-angle drives and vertical shafting. We should further compare the cost of repairs of the moving belts to the fixed copper conductor and the time and convenience for any changes

Walter Loring Webb.—I always supposed that one great point in this question of electric drives *vs.* belt transmission was the matter of the total power required in the engine room. I had always assumed, especially where the shops are very large and where the system of shafting would have to be very extensive, that the loss of energy between the engine and the various machines would total up to a very large percentage, and that the system of electric drives would result in some economy in that respect. I do not profess to know anything about it, but I would like to ask if tests have been made in regard to the relative economy of these two systems in that respect, irrespective of the advantages of having overhead cranes, etc.

Henry Hess.—In point of power to be provided there is very little difference between individual motor and line shaft driving; the central power plant capacity need not exceed one-fourth to one-third the aggregate of the various motors. But motors must be selected with reference to the maximum power requirements of the tools, not their average; as a result the individual motors are worked at less than their normal capacity and are therefore used uneconomically; that means that the saving due to elimination of line shaft friction is lost by this necessary uneconomical use of motors, so that there is little real difference in power efficiency. Still, individual motor driving is advantageous particularly as concerns the larger tools, which can then be run overtime without idly driving long lines of shafting. In such cases the individual motor is very economical. Again, certain tools are better brought to the work than the work to the tools; this is the general practice in some of the large electrical concerns. Other tools,

again, can be handled better with individual motors than with belts. The best arrangement for large shops is a grouping of smaller tools to be driven by short line shaft sections, each section having its own motor. Individual motors are used on the larger tools; on some of these several small motors are employed for various motions. My own practice has been to group all tools requiring less than 3 H. P. for belt driving and to use individual motors on all tools calling for 3 or more H. P. Naturally, this is not a hard and fast rule; tools otherwise coming under the first head may, by using individual motors, be placed at more advantageous locations where it would be awkward to use line shafts.

The President.—Such tests as Mr. Webb referred to have been made frequently, and have shown a decided saving in power when electric motors were used to replace shafting and belts. There is, however, a difference in different plants and it depends largely upon the nature of the plant how much more economical electricity will be. Each case must be considered by itself. As for what Mr. Hess said, I don't think he is quite right in saying that you replace the belt by an inefficient motor. I think most electric motors are far more efficient than the belts and shafting. In driving by belts there are generally several belts between the engine and the final power consuming machine, and the inefficiency has to be charged to the whole series of belts and shafting. As an illustration of a point raised by Mr. Barth, I would like to mention a case that came to my notice only a few days ago. It was a face lathe for objects of large diameter. By using a variable speed in making the cuts, you can increase the speed, in the exact proportion as the tool approaches the center, and in that way you can face off the plate in the minimum possible amount of time, because the cutting speed will then always be the same. That is only one illustration of the advantages of variable speed.

Mr. Walker, in his paper, said that it would be still more desirable to have a constant torque at variable speeds. This is not consistent with having a constant horse power; if this is to be done, then it must not be expected that the motor has the same power at all speeds, because the power of the motor will of necessity have to increase as the speed increases. In any such system as that, the motor must, of course, be relatively very large for the power at the low speed, as it will then be running far below its possible power. The difficulty has been to get the *same horse power* out of the motor at the variable speed, not the same *torque.*

Mr. Walker.—One thing, in defense of the variable speed drive, which may be emphasized, is shown in the first curve (Fig. 1). The table shows a similar result except that it is worked out for increase of feed; but the same principles would apply in regard to increase in speed. The first increase in speed will save a great deal more than any equal, subsequent increase in speed. A slight difference in speed cannot be accomplished between the steps of a cone pulley. With a variable speed motor this can be done, and I think a great deal of money is often lost by not increasing the speed only a very slight degree.

THE FREMONT METHOD OF DETERMINING THE FRAGILITY OF IRON AND STEEL.

THORSTEN Y. OLSEN.

Read December 3, 1904.

In this paper I will endeavor to explain the Fremont Method of Testing Iron and Steel. My knowledge of the subject is based mostly on translations which I have made, from the French, of Mr. Fremont's many papers to the Society for the Encouragement of the National Industry, together with a personal acquaintance with Mr. Fremont at Paris in 1900. In addition, I have been able to make various experiments on one of the Fremont machines at the laboratory of Tinius Olsen & Co.

To fully explain this new method and machine it is necessary to give the reasons for the desire for a new method, the comparison with other methods, and results obtained by this new method unobtainable in any other manner.

For several centuries past, methods of testing have undergone considerable changes; thus in the seventeenth and eighteenth centuries the test by a blow was considered as the foremost and hardest test for a steel to undergo. No exact means, however, was known at that time for determining the force of the blow, and hence the test was in a crude and uncontrollable form. The test by tension was also used at this time, but only became known as the principal form of testing after the middle of the nineteenth century. Thus, according to Mr. Fremont, the test of tension owes its great growth to research work on iron and steel by Mr. David Kirkaldy, in 1860, together with the development of the Bessemer steels. From this time the test of tension increased in importance, while that of shock or impact, as a factor, lessened.

With tension testing definite results may be obtained; in fact, the standard machines of to-day are by far more accurate than the homogeneity of the metal warrants. To-day all the formulæ on which engineering problems are based are derived from results obtained from tension testing. Standards have consequently been adopted for various materials, varying with the known stresses they may be subjected to.

Due to the lack of homogeneity of a steel and to the unknown stresses which must frequently take place, factors of safety are stipulated; thus, if a boiler, rail, or other structure is designed properly, it should break only by an unknown fault in the material. Accidents occur; but should they be called accidents when possibly they might be avoided? The defects in the steel are either lack of homogeneity or excessive fragility or both. While the manufacturer has been plodding on, testing his material as required, being then safe from further responsibility or criticism, the scientist has been endeavoring to obviate, to the best of his knowledge, these two faults of steel. The first fault, that of lack of homogeneity, may be eliminated only slightly by making a greater number of tests; the second, by an impact or shock test. To-day there is an impact test prescribed for a rail; why not for a boiler plate, wheel-tire, or any portion of a mechanism subjected at some time or other to an abrupt or intermittent stress?

The "fragility" is a known factor as far as the knowledge of its existence, but no further. Through lack of method, machine and standards, the consumer, together with the producer, have alike been compelled to ignore the fragility of their steel. Mr. Fremont, intent on relieving this state of affairs, and being in a position to fully investigate various methods of testing, commenced a series of investigations to determine the best means of testing for the fragility of steel.

In France, testing as done in this country is looked upon as an extravagance, and only the largest companies can afford a moderate size testing machine. The cost of the material and preparation of tension-test pieces are also considered a great expense, and hence Mr. Fremont, considering this together with the desire of testing portions of plates nearest to the portion actually used, and of testing thin plates, made his test specimen very small throughout his various experiments; thus, his specimens are 10 mm. wide by 8 mm. thick and 30 mm. long, with a notch cut crosswise in the center of one of its broad sides, 1 mm. wide by 1 mm. deep.

Fig. 1 shows the comparison of some tensile specimens with those of the Fremont type.

Mr. Fremont first experimented with the bending test, and bent his small specimens over a die 20 mm. long, with a punch-shaped tool in a machine, as shown by Fig. 2. This machine was arranged

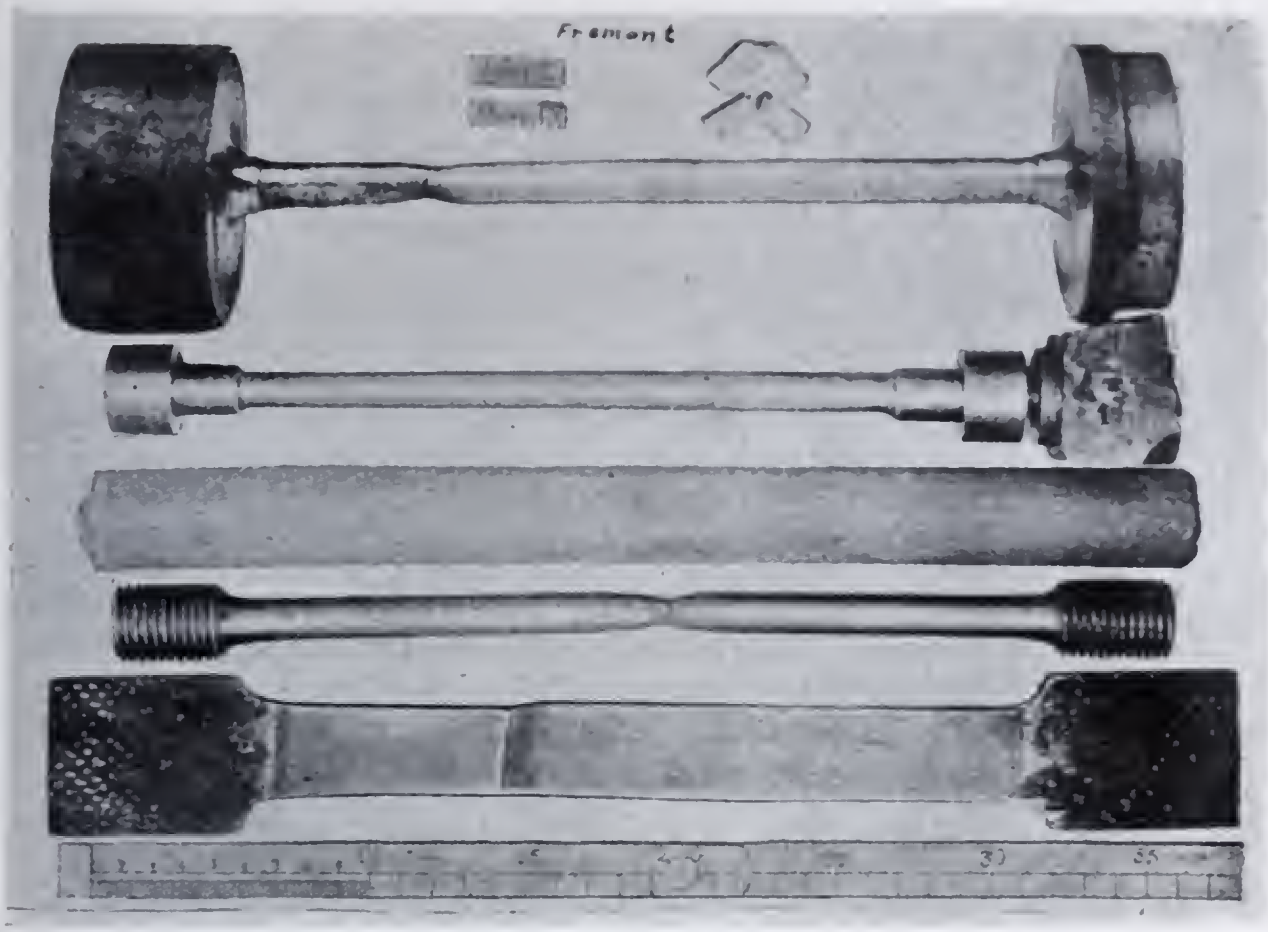


Fig. 1.

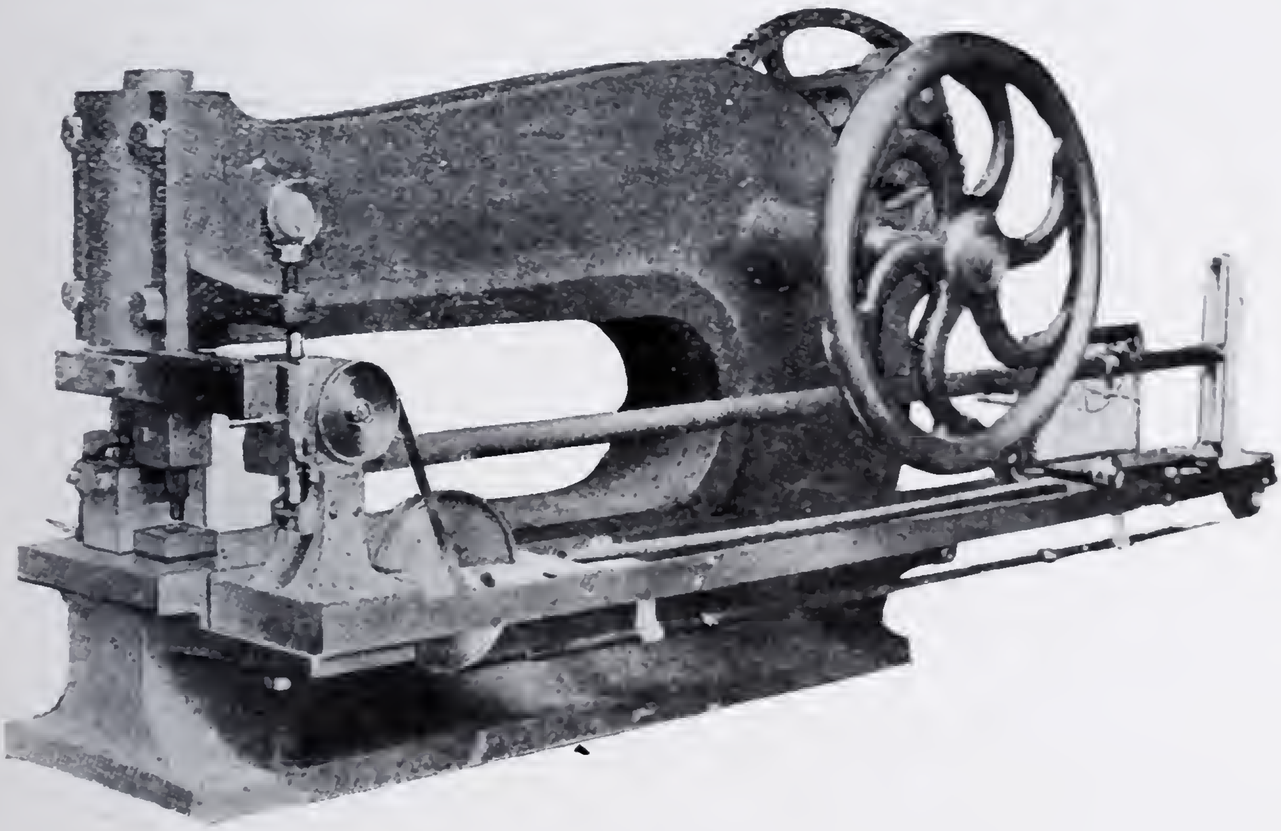


Fig. 2.

with an autographic apparatus for producing the stress-strain diagram of the test.

Now take two steels which have given approximately the same diagram by the tension test; call these two steels No. 9 and No. 16, as in A, Fig. 3. Subject this same material to a bend-

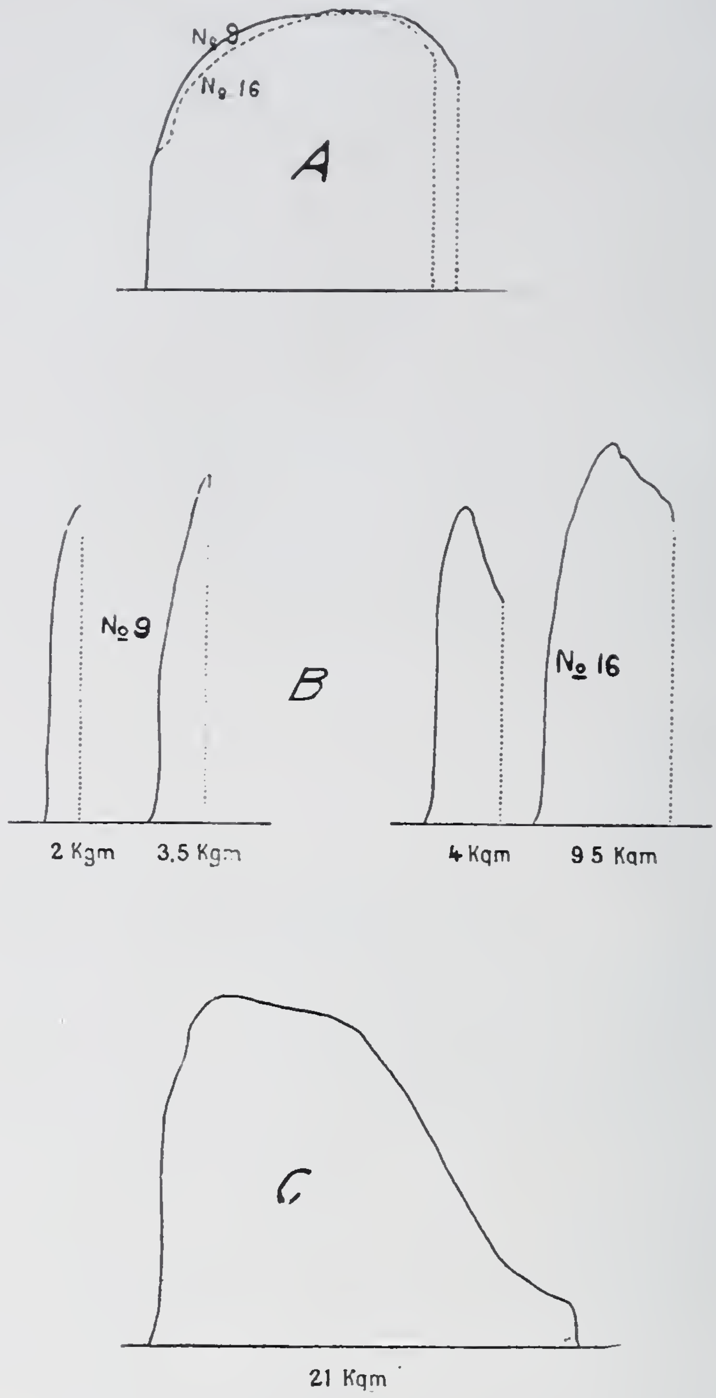


FIG. 3.

ing test. The second set of curves, at B, were obtained from these two steels tested both with the rolling and at right angles to it. These curves show that in both cases No. 16 broke with a greater amount of work than No. 9, although the reverse was shown by the test of tension. Then, again, at C is a bending diagram of a steel which

gave a similar tension diagram. This, as can readily be seen, gives a far better bending test than either of the other two steels.

These bending tests reveal some quality of the steel not revealed by the tension tests. Does the bending test reveal all? Will it reveal this quality on a less ductile steel?

Take a soft steel, prepare a specimen as formerly, placing a notch

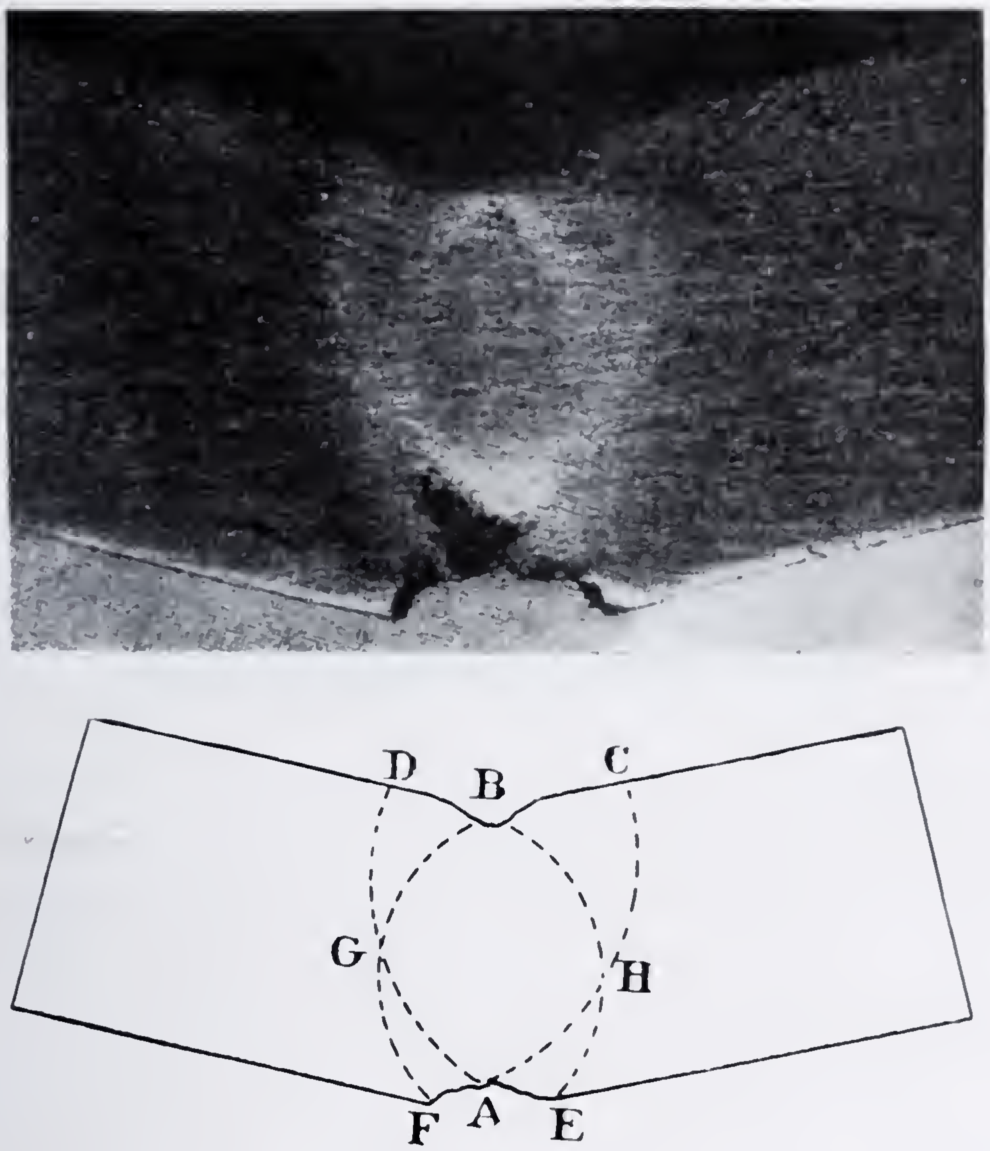


Fig. 4.

at its under side to reduce the elongation, then polish one side and submit it to a partial bending. The deformations are easily seen in Fig. 4. They consist of the interposition of two elementary deformations more distinctly shown in the diagram, Fig. 4. One deformation is that of swelling; the other, that of depression.

The depression E F G B H is nearly an ellipse, of which the major axis coincides with the line A B joining the point of impact to the notch. The swelling is a portion of the ellipse having the

same major axis as the preceding, but the extremities of the major axis do not coincide. The two ellipses have the part A G B H in common, and thus the two deformations are in part neutralized. The other portion of the ellipse produces the maximum deformations, and the rupture takes place along the synclinal lines G F and H E.

Take now the case of a fragile steel as shown by Fig. 5. In this case the ellipse caused by the compression or the swelling is reduced to nearly nothing. The rupture is made downward by tension fol-

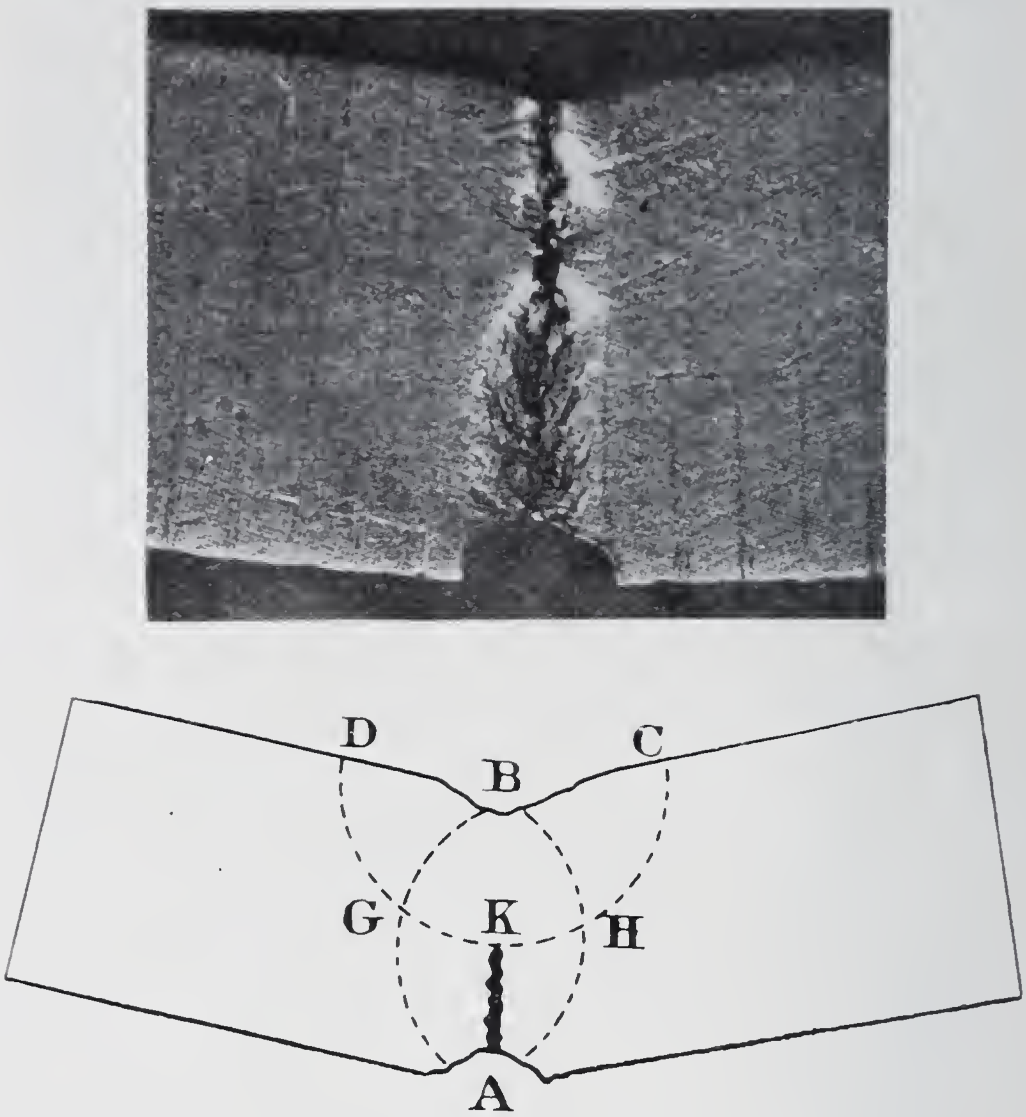


Fig. 5.

lowing the line A K in the diagram, and the rupture is effected abruptly with a very small expense of work.

For steels of intermediate quality, the two ellipses will vary from the one extreme to the other.

The rupture of these steels depends upon the position of the point K of the ellipse of compression. If the point K goes to A, the metal will not be weak, while if the point K rests in the neighborhood of point B, the metal will be extremely weak. Thus, both the promi-

nence of the swelling and the position of the point K are important factors in this determination for the fragility.

Here, again, in connection with these deformations, Mr. Fremont states that in the period of permanent deformations the neutral surface is neither parallel to the faces nor at equal distances from the faces. The position of this surface may vary with the condition of the test, and conditions being equal, with the quality of the metal; in other words, the more fragile the steel, the closer the neutral surface approaches the compressed side, and vice versa.

As the neutral surface is not at equal distance from the faces, especially for fragile steels, the idea is inferred that a difference exists between the elastic limit for tension and for compression; thus Mr. Fremont, in a note to the French Academy of Science, stated that "a steel is fragile—that is to say, it breaks abruptly by bending with the expenditure of a small amount of work—or non-fragile—that is to say, it breaks slowly in exerting a quantity of work proportional to that exerted for rupture by tension—according to whether the ratio of the elastic limit of tension to the elastic limit of compression is less or greater than unity." This would not be an absolute means of judging the fragility, as the elastic limits would be taken from static tests, and not by means of a blow or impact.

In the eighteenth century a merchant tested his steel by examining the break after rupture, by knocking the same with a hammer. Then, later, repeated blows of the same hammer from a given height were tried; but neither of these gave any definite results on the fragility of the material.

In 1722 the great scientist Réaumur measured the hardness of steel by the number of blows of a hammer necessary to make a chisel penetrate to a certain depth. This method was long and tedious and also lacking in results.

It has been proposed to require all steel to stand a certain drop of a hammer, and keep this a standard. Then, however, two points for discussion would arise:

First, The possibility of an arbitrary appreciation of the commencement of rupture.

Second, the total resistance of the metal could not be measured.

Let us take a slightly different form of drop testing. Take a bar and mark it off by small notches and place it under a hammer, dropping the same through successive heights, until a point is reached where an increase or decrease will rupture or prevent rupture of the

bar. This gives the result only after testing a great number of bars; it also supposes the metal to be homogeneous; and finally it does not reveal accurately the fragility of the steel, because a steel breaking with an amount of work equal to N ft. lbs. produced by a height of fall equal to P will break with a quantity of work less than N produced by a fall greater than P. To illustrate this, Mr. Fremont took from the same steel, six specimens of the same size, and marked them 1, 2, 4, 5, 6, and 3. He then tested them by shock at increasing speeds of from 1 meter to $1\frac{1}{2}$ meters. These specimens so

FIG. 6.

broken are shown in Fig. 6. The first five appear about the same, the sixth, or No. 3, alone being broken off abruptly. The metal had thus become fragile for a speed of $1\frac{1}{2}$ meters.

To explain this fact it is supposed that the transmission of the forces in the material is not instantaneous and so depends on the speed of impact. The volume of the metal concerned will vary inversely with the speed of impact. In the product of the resistance by the deformation, the factor "deformation" decreases as the speed of impact increases, and the rupture will be made with a less expenditure of work.

The scientist Carnot, in 1889, stated: "If we suppose a steel or iron submitted to a continuous slow force, it is understood perfectly that this persistent force transmits itself successively from molecule to molecule in such a manner that all the molecules are submitted to like forces. In the contrary case, when the force is abrupt or instantaneous, it is understood that all the molecules touched can be disaggregated from the beginning while the other molecules will support no apparent effort." According to this, then, metals can exhibit very different qualities when submitted to a slow force or to an abrupt one.

In tension testing the speed is a more or less important factor, depending on the ductility of the steel, and it is well known that an increase of speed increases the resistance of the metal, but decreases the elongation.

By comparing tests effected by rupturing specimens by a repetition of blows and by a single blow Mr. Fremont found that some steels ruptured by a single blow required but one-third to one-fourth the amount of work required by the repeated blows, and thus impact testing employing a repetition of blows is little better than a bending test. Steels appearing non-fragile by the first method would appear fragile when subjected to a single drop of a hammer just sufficient to break the bar.

As the shock test varies with the speed of impact and the deformations become smaller, the fragility slightly shown in the bending test will appear in its true form in the impact test.

The rate of molecular transmission of force through a steel may be one way of defining this fragility. It is also a fact that for the same steel this rate approaches a limit independent of the speed of impact when twice that sufficient to rupture the specimen.

Knowing the desirability for an accurate and easy means for shock testing, Mr. Fremont presented a communication to the Academy of Science in 1897 proposing a method of registering the amount of work required to produce rupture by this means.

As the speed of impact is a great factor, it is necessary to make the speed of the hammer sufficiently great to rupture the specimen with one blow, whatever the quality of the metal. If a steel then proves non-fragile to a drop of this kind, it has been proven non-fragile to the test of a cannon. To determine the amount of work absorbed to produce this rupture, it is necessary to measure the residual work that is possessed by the hammer after rupture of the specimen. After numerous tests by shock Mr. Fremont finished a

machine embodying principles by which this residual force could be measured. First, "crushers" were employed from which the residual force in the hammer could be measured from their known compression; this, however, was not very practical, and so in the commercial machine a set of springs is used to measure this residual force.

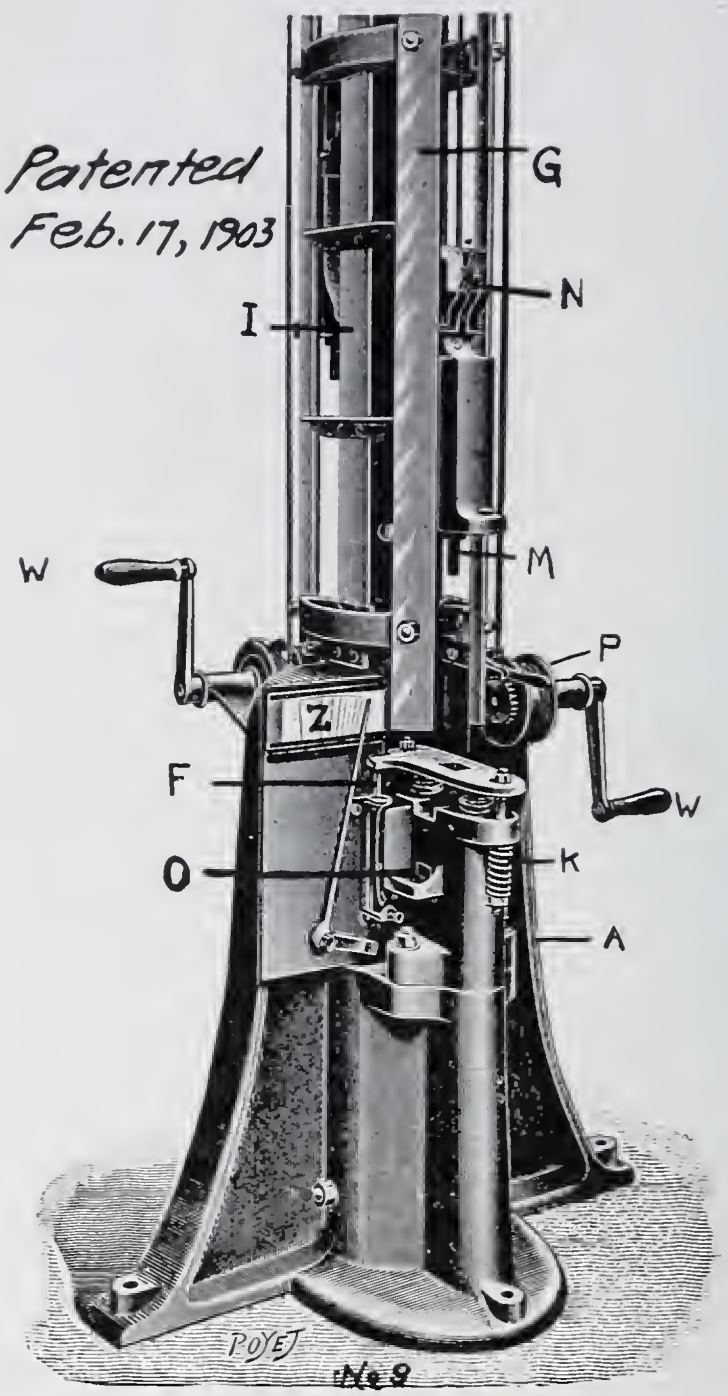


Fig. 7.

The machine as built to-day is shown in Fig. 7. This figure represents the lower portion of the machine. The design is made double: *i. e.*, it is arranged so that two may operate on the same machine at the same time. The base of the machine is composed of two parts connected by bolts. Between them, and held tightly

by them, is a central I-beam marked I. This carries six cast-iron supports, at intervals, to which are bolted the four rolled steel guides marked G. Two anvils are bolted on opposite sides of the base, the whole weighing more than 1500 lbs. The weights of the hammers are 20 and 30 lbs., or about $\frac{1}{70}$ the total weight of the machine. The anvils marked A contain in front and in back of the matrix vertical cylindrical holes serving for the lodgment of two springs. A cap of hard steel is placed directly over them. It is this cap or platform which receives the hammer after the rupture of the specimen.

The hammer compresses the springs and the space traversed by them is then measured. As the springs rebound after the blow, it violently repells the cap, and so to offset this new shock the cap is held by two small springs, one of which is visible on the front of the anvil at K. These springs thus serve merely as a deadener to the cap when rebounding.

On each side of the base and to the right of the operator is a windlass marked W, by which the hammer is easily and quickly raised. A ratchet and lever placed at P prevent the downward motion of the hammer when placing the specimen in position.

Each hammer has inserted at its lower extremity a hardened steel punching tool, as at M. A gripping device at N, holds the hammer to the pulling cord until automatically released at the top of the machine.

To operate the machine we first raise the weight enough to allow room to place the specimen in position, notch side down, with notch directly in the center of the die. Then we turn the windlass, raising the weight to the top, where it is automatically released, and falling, breaks the specimen, which in turn falls through the die into the pocket at the side of the machine. Having broken the specimen, it is necessary to measure the work required to cause the rupture. The cap covering the springs pushes down a light steel tube at F, which is held by friction so as to give an accurate measurement of the deflection of the springs. This deflection is further multiplied by the aid of the instrument shown at Z.

To calibrate the machine the hammers are raised through successively increasing intervals of height and dropped on the platen covering the springs. Corresponding marks are placed on the card of the instrument, as shown. Thus, the machine can readily be calibrated at any time with about ten minutes' work.

Let us now summarize the advantage obtained by this method and machine.

1. The method, by using small specimens, reduces the cost of test pieces and their preparation, thereby furthering the great production of tests and thus aiding in establishing a standard homogeneity test.

2. The small specimen permits of testing thin plates, both with and across the rolling, as well as the possibility of testing parings, or clippings from actual material used, or those nearest to any section subjected to the greatest known stress.

3. The machine affords an accurate method of measuring the work necessary to produce rupture under standard conditions, always maintaining the same speed of impact. The machine as manufactured in this country will have a standard drop of 13 feet with hammers weighing 20 and 30 lbs., as these are the nearest English units to that used in the metric system.

The specimen will be $\frac{3}{8}$ inch wide, $\frac{5}{16}$ inch thick, and $1\frac{1}{4}$ inches long, with a saw-cut $\frac{1}{16}$ inch deep. The die is $\frac{13}{16}$ inch wide. The machine can be shifted from the one standard to the other without any material change. The specimens may be prepared either by hand or in quantity, by a small machine constructed for the purpose.

To determine the influence of the dimensions of the notch on the results of the tests Mr. Fremont made three series of tests; first, with depth equal to the width; second, width equal to twice the depth; third, depth equal to twice the width. In the bending test he found that double the width required the same maximum force to commence the rupture, but required more work to complete the same. Double the depth required less force to commence the rupture.

Making these same tests by the drop of the hammer, Mr. Fremont found that a small variation in width was not discernible and only the case of double the depth created a difference in the results. The more fragile the steel, the less important would be a small variation in the size of the notch. Some results obtained by the Fremont drop test, compared with the other forms of testing, were tabulated by Mr. Fremont as shown in the accompanying tables. The upper table beginning from the left, gives the results of the tension test, bending test, and shock test, with notch made both with a hacksaw and with a milling cutter. The lower table is that of some non-fragile steels, showing the tension test to the left, with the percentage of elongation and the average maximum and minimum work required to cause rupture by shock. From these results it is readily seen how fragile some steels are to shocks, while differing but little

in the tension test, while steels passing the bending test also fail when subjected to the drop test.

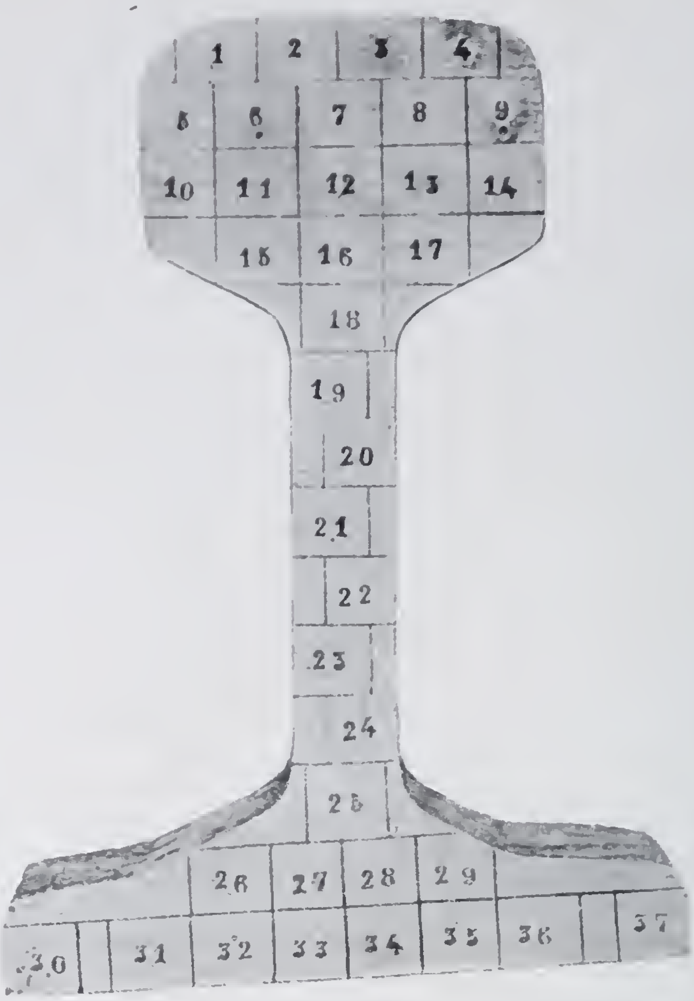
Tension Test.		Static Bending.		Bending by Shock.			
				Notched by a Saw.		Notched by a Milling Cutter.	
Tensile Strength. Kilog.	Elongation in 20 Cm. Percentage.	Lengthwise. Kgm.	Crosswise. Kgm.	Lengthwise. Kgm.	Crosswise. Kgm.	Lengthwise. Kgm.	Crosswise. Kgm.
47	24	9.5	8	13	6	10	6.5
60	25	4.5	2.5	4.5	4	6	6
44	28	12.5	10	6	6	6.5	4.5
37	30	22	20	9	7	1	7.5
33	25	12.5	2	9	3	3	2
33	32	21	20	5.5	3	4	3.5
45	27	5.5	6	3	4	5.5	4.75
60	22	15.5	4	7	3.5	6.75	3
50	20	5.5	12	7	5	6	4
40	23	22.5	17.5	22	13	21	19
53	23	4	3	5	2.5	5.2	3
49	27	20.5	6	22 19.5 21.5 21.5	5	24 21.5 21.5 24	4
46	27	25	12	30.5 29 29 26	17.5 18.5	26.5 26 30	16 17.5 17
43	28	22	19	24.5 25 25.5 30	22.5 19 21.5	22.5 23 24	19.5 23 23.5
50	26	24.5	6.5	20 22 22.5 23	5 5	22.5 22.5 21.5	4.5

SPECIMENS TESTED WITH THE ROLLING.

Tension Test.		Shock Test.		
Tensile Strength. Kilog.	Elongation in 20 Cm. Percentage.	Average Work. Kgm.	Maximum Work. Kgm.	Minimum Work. Kgm.
39	30	28.80	32	23.50
42	28	25	30	22.50
43	30	27.30	30	24.50
45	22	25.40	29	22.50
46	28	25.40	30.50	26
49	27	21.50	24	19.50
50	25	22.35	25	20

SPECIMENS TESTED ACROSS THE ROLLING.

Tension Test.		Shock Test.		
Tensile Strength. Kilog.	Elongation in 20 Cm. Percentage.	Average Work. Kgm.	Maximum Work. Kgm.	Minimum Work. Kgm.
37	25	21.43	23.50	19
38	"	20.50	24	18
40	"	21.7	23	19.50


1 2 3 4
5 6 7 8 9
10 11 12 13 14
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26 27 28 29
30 31 32 33 34 35 36 37

Fig. 8.

Fig. 9.

Fig. 8 represents a section of a rail showing the method of cutting out Fremont specimens from the entire section. Thus, any rolled form can readily be tested to determine the effect of the rolling on any portion of it. The rail after the test, appears as shown in Fig. 9, the pieces bent having been subjected to the bending test, while those appearing broken abruptly were tested by shock.

The Fremont method and machine received the gold medal at the Paris Exposition in 1900 and were discussed at the International Testing Congress in session at that time.

DISCUSSION.

James Christie.—It has long been believed by many inspectors that the ordinary tension test does not always disclose the fragility of defective steel. Instances are known where untrustworthy material has behaved in a satisfactory manner under tensile test. It has been asserted that this faulty material would show insufficient ductility if submitted to impact tests.

It is true that the experiments of Prof. Hatt at Purdue University showed satisfactory ductility under impact, but this might not have occurred with defective material. When the falling weight or height of fall is varied in drop tests, it is inconvenient and difficult to establish any exact comparison, under these varying conditions, but the Fremont method of maintaining a constant weight and height of fall, and measuring the residual energy of the drop after fracture of the specimen is interesting and promising.

The President.—Would the depth of the saw-cut in the sample make considerable difference?

T. Y. Olsen.—Yes; slight variations in the depth will make slight differences in results, the difference being more noticeable on better material. This was explained in the latter part of the paper by Mr. Fremont's experiments on that particular point in question.

The President.—Suppose some specimens turned out to be very good in testing them with this machine, for what purpose would such steel be most useful? In other words, just what good qualities would such a test show?

Mr. Olsen.—I think if a steel would answer the Fremont test it would be the steel for any class of work, or any purpose. A steel should be tough. A steel can be hard, still not fragile. All machine tools, cutting tools, or structures are some time or other subjected to shocks or intermittent stresses. Mr. Fremont took rails or boiler plates as examples; he also made tests on some conduits and on steel bars for structural work, which broke, due to their fragility, thereby causing great damage. Accidents of this nature influenced Mr. Fremont to continue his great research work along this line.

The President.—Boiler plates are not subjected to sudden blows like a rail.

Mr. Olsen.—I do not know exactly what occurs in the boiler to cause the explosion which fractures the plates. Since so many boilers fail through fractured plates, it is plausible that some shocks or equivalent must occur. The great variations in the pressure and temperature stresses alone might be termed

a repeated stress and as damaging to a steel as a sudden heavy blow, causing the rupture just as surely, only in a greater length of time.

The President.—The difference in the rapidity of the applied force is shown by an experiment which is familiar to all, and I therefore mention it here. In a material like pitch, for instance, it is well known that you can take a piece and pull it out slowly into threads, it will be so very elastic; yet, when suddenly struck with a blow it will splinter like glass. It is not unreasonable to suppose that iron and steel may have this same quality, only to a different degree; and it seems as though the experiments described in the paper show this to be the case. Would not the relative results between a number of specimens be quite different, depending upon the height from which the weight is dropped? In other words, if one person had a machine in which the drop is thirteen feet, as I believe it is in this machine, and he tested a lot of materials and arranged them in their order of merit; then if another person used a machine in which the drop was perhaps twice as great, would not the relative order of those same specimens turn out differently in the second case than in the first, because the rapidity of the blow is quite different?

Mr. Olsen.—The height is to be kept a constant. That is one of the essential points of this method. Mr. Fremont made some experiments, and found that, if the height of fall were possibly twice or more times as great as that necessary to produce rupture of the specimens, a further increase in height would not vary the results of the test. A limit seemed to be reached where the rate of transmission of the forces through the molecules would not change. Thus, in the example before mentioned, since the height of fall in this machine was experimentally determined as beyond the limit in question, a height three or four times as great would not change the results of the test; but a great decrease in height, on the other hand, would make considerable variation.

The President.—In either case the specimen must be broken?

Mr. Olsen.—The specimen is broken in every case. The machine is provided with two sizes of hammers, so that if the hammer on the one side is insufficient to cause rupture, the other is resorted to. The speed of the two hammers is practically the same, but slightly greater for the heavier hammer. Beyond the limit before mentioned, the results, as obtained with either hammer, should be the same.

To calibrate the machine I measured the column off in feet and raising the hammer let it drop successively from the heights so marked off, inscribing a mark on the dial plate of the instrument after each fall. This marking was verified by dropping the hammer from the same height several times and noting that the mark came to the identical place each time.

The needle on the instrument is not in contact with the moving parts of the machine during the test. After the test is completed the needle is moved until its lower extremity makes contact with the tube compressed by the platen covering the springs; thus there is no inertia to be considered as regards the action of this pointer during the test. The pointer is so constructed that it falls away from the tube and is only in contact with the tube when held so by hand for the purpose of measurement.

George M. Sinclair.—Have you tried materials other than ordinary carbon steels? For example, have you tried nickel steel? It would seem that either

the height of fall or the weight of the falling part would have to be varied to give the machine a wide range over materials of various kinds. In ordinary testing we ignore heating of the bar. I can recall one case, however, where a serious effort was made to take into consideration the temperature of the bar at breaking. Speaking from memory, I should say that this was some time between 1870 and 1880, when Professor Thurston undertook an extended investigation into the physical qualities of steel for the United States Government, and Mr. William Kent made many of the experiments. One series was made with a freezing mixture applied to the bars to determine the effect of low temperature. The control of the temperature, however, was very imperfect and the bars were quite warm after breaking. The impact machine under consideration should add considerably to our knowledge of the effect of temperature on steel.

For testing a wide range of material it would seem to be necessary to vary the falling weight if the height through which it drops is maintained constant. Perhaps eventually each material will be tested by a specific weight and height adopted as standard for that material. The use of springs suggests trouble, and it would seem desirable to be able to change them readily and also to calibrate them frequently. I presume they can be tested in position by dropping the hammer directly on them through known heights, say at every foot of height. With springs which are known to be correct, on the other hand, the readings of the registering apparatus can be calibrated. I should like to inquire how close you can read,—that is, the sensitiveness of the machine, and also its accuracy.

Mr. Olsen.—Mr. Fremont claims an accuracy of between 1½ and 3 per cent. As far as calibrating goes, that is very easy. All you have to do is to raise the weight to different heights. You can do that in five or ten minutes' work. You ought to be able to make a good many tests.

NOTE ON THE SUMMATION OF STRESSES IN CERTAIN STRUCTURES.

CARL HERING.

Read December 17, 1904.

At a recent meeting of this Club a question arose incidentally concerning the variations in stress in a member of a mechanical structure under certain conditions. The animated discussion to which it gave rise showed that opinions differed quite decidedly and were firmly held. As the case is one which occurs frequently in practice, and as incorrect and incomplete solutions are published in some text-books and appear to be used not infrequently in practice, the writer thought the matter to be of sufficient importance to warrant making a complete analytical investigation of it.

The problem, which occurs in practice in many different forms, may be represented in its simplest form by the following illustration. Let A and A, Fig. 1, be two tension members held together by a bolt, B, which is put under permanent initial tension by having its nut screwed down tightly. If under these circumstances a tension is applied to the member A, A as a whole, the question is: *is this tension added to that already existing in the bolt.* In other words, must the bolt be made strong enough to withstand the *sum* of the two strains. The bolts securing the cylinder head of a steam engine, or the bands around a wooden stave pipe for high water pressure, are fair illustrations of this problem occurring in practice.

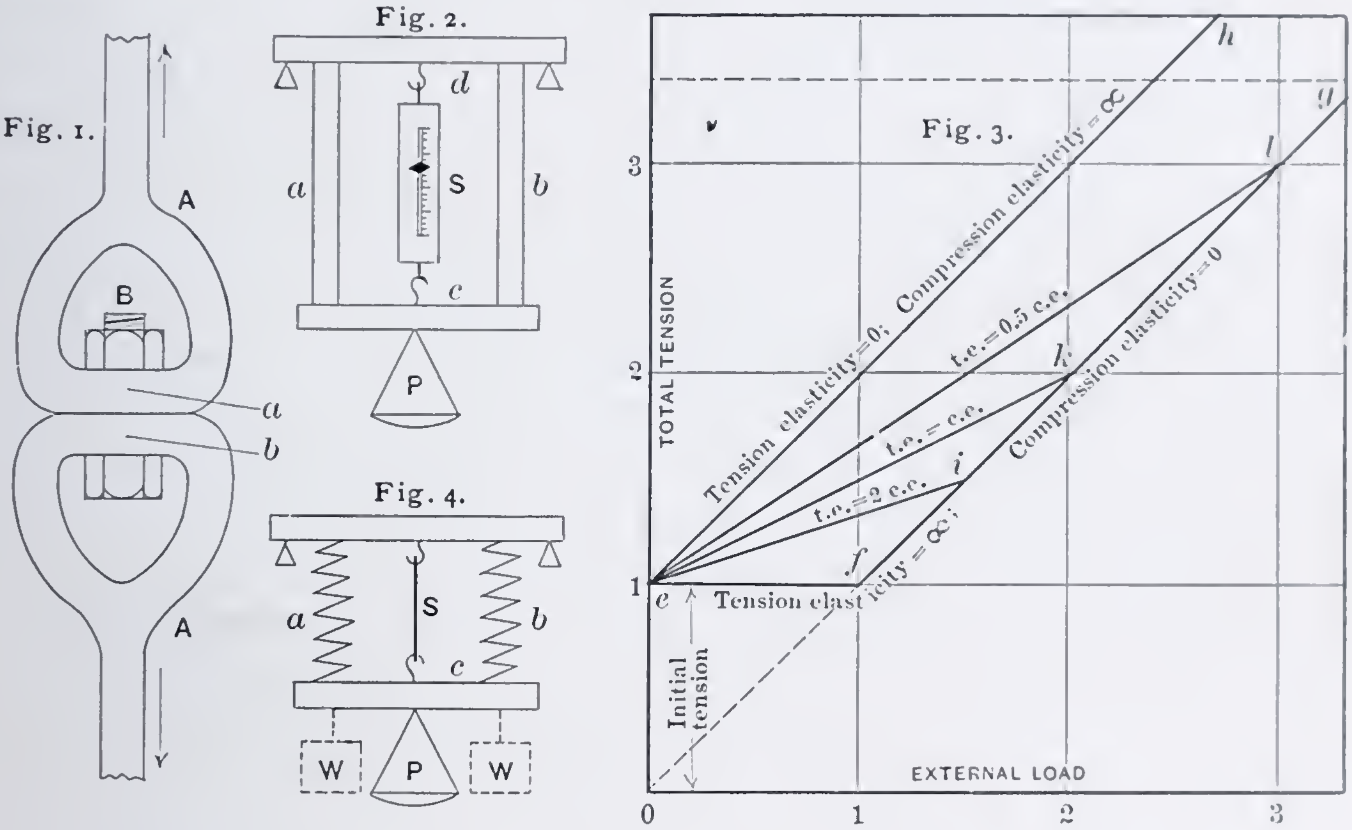
One of the reasons why differences of opinion are held is that this apparently simple question does not admit of being answered by a mere yes or no; it depends on the conditions, as will be seen in the solution given below.

Some twenty-five years ago, when this same question arose, the writer made the following simple experiment: Referring to Fig. 2, *a*, *b*, *c*, and *d* are four blocks of wood held together by an ordinary spring scale, S, under tension, as shown. A scale pan, P, was attached to the lower block, and the whole system was suspended as shown.

In this apparatus the scale, S, represents the member under tension, and corresponds to the bolt, B, in Fig. 1. The members *a* and

b are the members under compression, and correspond to the parts *a* and *b* in Fig. 1, which are compressed by the bolt. Weights placed in the scale pan, P, represent the additional and variable strains or loads applied externally to the system as a whole.

The initial tension on the tension member, S, was adjusted to be 10 lbs., as shown by the reading of the scale; hence the compression of members *a* and *b* was also 10 lbs. Weights were then placed in the scale pan, P, one pound at a time, and it was found that for all weights less than the initial strain of 10 lbs. the reading of the scale remained constant,—namely, 10 lbs. This showed conclusively that under these conditions the externally applied strain was *not* added



to the initial strain on the tension member, contrary to what is often claimed. The effect of the weights in the scale pan was *to diminish the compression* on the members *a* and *b* and not to add tension to the other. With 10 lbs. in the scale pan, the compressive strain on *a* and *b* was released entirely, and these members could then be withdrawn without changing anything in the system.

When the weights in the scale pan were in *excess* of the initial stress of 10 lbs., the stress on the tension member, S, of course increased by exactly the same amount. But this is of less interest, as it would in most cases be beyond the range occurring in practice, because it means a leakage in such cases as cylinder heads, wooden stave pipes, etc., mentioned above.

This experiment therefore clearly proved beyond question that, *under those conditions* and up to that limit, the member under tension will not be subjected to a greater tension by external forces than the original tension applied to it by screwing down the nuts sufficiently to prevent leakage.

During the above-mentioned discussion at this Club it was stated that the elasticity of the members under tension and compression would modify the result. The writer therefore extended this investigation to include the effects of these elasticities, and has found the following results, which seem to form a complete solution of the problem.

It was found by this investigation that the elasticities effected the results very greatly, and that the final strain on the tension member varied greatly with the *relative* elasticities of tension and compression of the two members.

The curves of results are *broken lines,* and therefore a graphical representation is preferable to an algebraic one, besides being more comprehensive and less liable to mislead. They are shown in Fig. 3 for the two extreme, limiting cases and for three intermediate values.

The first limiting case is when the elasticity of the compressive member is supposed to be zero and that of the tension member is infinity, or, in practice, when the elasticity of tension is very great as compared with that of compression; a fly wheel whose spokes are under initial tension due to shrinkage might belong to this class. This is the case shown in Fig. 2, and has already been discussed; the spring scale was very elastic and the blocks quite inelastic. The beams *c* and *d* are, for simplicity, considered to be inelastic and therefore eliminated, as in most problems they do not exist and when they do their elasticity may be considered together with that of one of the essential members.

The curve for this case is the broken line *e-f-g* in Fig. 3. In this curve sheet the vertical distances represent the total tensile strains on the tension member. The horizontal distances represent the *externally* applied tensile strains or loads, such as the steam pressure in a steam cylinder or the water pressure in a wooden stave pipe. The initial tensile strain—that is, when there is no external strain—is shown by the horizontal line *e-f,* and, to make the solution a general one, this strain is here represented by unity.

From this broken line *e-f-g* it will be seen that, as external loads are added, the tensile strain remains constant—that is, the line is

horizontal—up to a point, *f*, when the external strain is equal to the initial; after that, the tensile strain increases pound for pound with the external load, and is always equal to it, as has already been shown in connection with Fig. 2.

In practice this case arises when the tension member has a small cross section and is relatively long and elastic, and when the reverse is the case with the compression member.

In the other extreme limiting case the elasticity of compression is supposed to be infinite and the elasticity of tension zero, or, in practice, the elasticity of tension is very small as compared with that of compression, as, for instance when an elastic gasket is used under a cylinder head. This case is represented by the line *e-h*. In this case the total tensile strain increases pound for pound, with the external strain, from the start, and it is always equal to the *sum* of the external and the initial strains.

Such a case might be represented by Fig. 4, in which the members under compression, *a* and *b*, are shown as extremely elastic springs, while the tension member is a relatively inelastic wire, S. In such a case the springs may be considered as the equivalents of permanent weights, W, shown in dotted lines, because the force with which they act on the beam, C, is always constant even for a slight elongation of the wire, S. When thus replaced by weights it becomes self-evident that the strain on S must always be equal to the sum of the initial strains, W + W, and the additional weights, P. In practice this case arises when the tension member has a large cross section and is relatively short and inelastic, and when the reverse is the case with the compression member. Perhaps wooden stave pipes would come under this case, as the wet wood which is under compression is very elastic relatively to the thick steel bands.

The results under all other conditions must, of course, lie between these two limits, represented by the curves *e-f-g* and *e-h*. They are all broken lines extending from the point *e* to the line *f-g* and then coinciding with the latter. They are here drawn for three intermediate cases, thereby clearly showing the law which governs all cases and enabling correct calculations to be made when the relative elasticities are known.

When, for instance, the elasticity of the tension member is double that of the one under compression, *e-i-g* will be the curve; it shows that one-third of the externally applied load must then be added to the initial strain of the tension member, up to the point *i*, at which

the external strain is one and a half times the initial, after which the total tensile strain increases as the external load does, and is equal to the latter.

When the elasticity of the tension and compression members are equal, the curve is *e-k-g*, which shows that half of the externally applied load must always be added to the initial strain of the tension member. The turning point, *k*, is reached when the external load equals twice the initial strain.

Lastly, when the elasticity of the tension member is half that of the compression member, *e-l-g* is the curve; two-thirds of the external load must then be added to the initial strain. The turning point, *i*, then occurs at three times the initial strain.

It should be clearly understood that by the elasticity is here meant the *actual* elasticity of the member under strain; that is, the actual amount of the elongation or compression when under the particular stress, and not the coefficient of elasticity per unit cross section and length. A member made of a very elastic material might be so large, or the force acting on it so small, that the actual change of dimension is still very small.

Referring again to Fig. 3, it will be noticed that the points at which leakage would occur in a case like a cylinder head or wooden stave pipe, are the turning points *f*, *i*, *k*, *l*, etc., all of which are on the 45-degree line. This point is therefore the more remote, the greater the compression elasticity and the less the tension elasticity, which is self-evident. The line representing the point of rupture would in this diagram be a horizontal line in the upper part of it, as indicated by the dotted line. This shows that, within the leakage points, the point of rupture is the more remote, the less the compression elasticity and the greater the tension elasticity. Or, in other words, exactly the reverse conditions as those for the point of leakage.

ABSTRACT OF MINUTES OF THE CLUB.

Regular Meeting, October 1, 1904.—President Carl Hering in the chair. Sixty-five members and visitors present.

Mr. Washington Devereux presented a paper on "Some Causes of Fire."

Regular Meeting, October 15, 1904.—President Carl Hering in the chair. Seventy members and visitors present.

Mr. John Birkinbine presented a paper on "Some Applications of Wooden Stave Pipe."

Regular Meeting, November 5, 1904.—President Carl Hering in the chair. Eighty members and visitors present.

The death of Henry I. Snell, active member, on Oct. 20, 1904, was announced.

Mr. Geo. S. Webster, Chairman of a special committee of the Club on the park movement in Philadelphia, made some introductory remarks on the acquisition of a comprehensive park system for Philadelphia. Mr. Andrew Wright Crawford, Secretary of the Organizations Allied for the Acquisition of a Comprehensive Park System for Philadelphia and Secretary of the City Parks Association, spoke of the recent park movement throughout the country, and showed, by means of lantern slides, what other cities are doing. Mr. Frank Miles Day, Vice-President of the American Institute of Architects, showed the opportunities for the acquisition of parks and parkways in the vicinity of certain built-up parts of the City. Mr. Leslie W. Miller, Chairman of the Allied Organizations, Secretary of the Fairmount Park Art Association and Principal of the School of Industrial Arts, pointed out the great benefits to be derived from the proper treatment of the Schuylkill water front within the City limits.

Business Meeting, November 19, 1904.—President Carl Hering in the chair. Eighty members and visitors present.

The Nominating Committee presented the following nominations for officers:

For President,	Silas G. Comfort.
For Vice-President	George N. Leiper.
For Directors,	John T. Loomis. W. P. Dallett. Henry H. Quimby.
For Secretary,	Walter L. Webb.
For Treasurer,	Geo. T. Gwilliam.

The special Committee on the Park System for Philadelphia offered the following resolution, which was adopted by the Club:

"*Resolved*, That The Engineers' Club of Philadelphia co-operate with the Organizations Allied for the Acquisition of a Comprehensive Park System for Philadelphia and lend its support to this object."

Mr. E. L. Walker (visitor) presented a paper on "Electric Drive."

The Tellers reported the election of Messrs. John G. Brown, Wm. McClellan,

John C. Parker and Oscar Schmidt to active membership, and Mr. J. A. Duross to associate membership.

Regular Meeting, December 3, 1904.—President Carl Hering in the chair. Seventy members and visitors present.

Mr. Thorsten Y. Olsen presented a paper on the "Fremont Method of Determining the Fragility of Iron and Steel."

Business Meeting, December 17, 1904.—President Carl Hering in the chair. Eighty-five members and visitors present.

Mr. Jos. B. King was nominated for the office of Vice-President.

Mr. Thos. C. McBride presented some notes on the Coolgardie Water Supply, and Mr. Carl Hering presented a "Note on the Summation of Stresses in Certain Structures."

ABSTRACT OF MINUTES OF THE BOARD OF DIRECTORS.

Regular Meeting, October 15, 1904.—Present: President Carl Hering, Vice-Presidents Foster and McBride, Directors Loomis, Leiper, Bonner, Davis, Devereux, Easby, the Secretary, and the Treasurer.

The Treasurer's report showed:

Balance, May 31st,	$2111.34
Receipts, June, July, and August,	561.75
	$2673.09
Disbursements, June, July, and August,	$1575.04
Balance, August 31st,	$1098.05
Balance, August 31st,	$1098.05
Receipts, September,	215.75
	$1313.80
Disbursements, September,	357.60
Balance, September 30, 1904,	$956.20

The Library Committee reported that all books in the library had been catalogued. It was resolved that the Club retain twenty-five copies of each number of the "Proceedings" published prior to 1901, disposing of all extra copies published during this period at five cents apiece.

Regular Meeting, November 19, 1904.—Present: President Carl Hering, Vice-Presidents Foster and McBride, Directors Loomis, Leiper, Davis, Easby, the Secretary, and the Treasurer.

The Treasurer's report showed:

Balance, September 30, 1904,	$956.20
Receipts, October,	499.75
	$1455.95
Disbursements, October,	414.03
Balance, October 31, 1904,	$1041.92

The Library Committee submitted a letter from Past-President Joseph T. Richards, accompanying a picture of the Pennsylvania Railroad bridge over the Susquehanna River at Rockville, Pa. The Secretary was directed to thank Mr. Richards on behalf of the Club.

An appropriation of $75.00 was made for re-connecting the electric wiring of the Club House by a permanent connection.

Regular Meeting, December 17, 1904.—Present: President Carl Hering, Vice-Presidents Foster and McBride, Directors Leiper, Devereux, Easby, the Secretary, and the Treasurer.

The Treasurer's report showed:

Balance, November 1, 1904,	$1041.92
Receipts, November,	610.25
	$1652.17
Disbursements, November,	718.86
Balance, November 30, 1904,	$933.31

The following resignations were accepted: Benj. Adams, W. S. Auchincloss, Chas. Dunn, Wm. R. Dunn, Geo. G. Hood, Percival Roberts, C. E. H. Sudler.

ADDITIONS TO THE GENERAL LIBRARY.

From J. T. Oakley, Commissioner, Dept. of Water Supply, New York.

Report of the Commission on Additional Water Supply for the City of New York.

From Fairmount Park Art Association, Philadelphia.

Thirty-second Annual Report of the Board of Trustees.

From Harvey Linton, City Engineer, Altoona, Pa.

Municipal Manual, City of Altoona, 1904–05.

From Emile L. Nuebling, Supt. and Engineer, Reading, Pa.

Thirty-ninth Annual Report Board of Water Commissioners.

From University of Illinois, Urbana, Ill.

Bulletin No. 1, Engineering Experiment Station.

From University of Pennsylvania.

Proceedings of Commencement, June, 1904.

From G. Henriksen, Christiania, Norway.

The Iron Ore Deposits in Sydvaranger, Finmarken, Norway, and Relative Geological Problems, 1902.

From Derrick Publishing Company, Oil City, Pa.

Pure Oil Trust *vs.* Standard Oil Co., 1899–1900.

From Peace Association of Friends, Philadelphia.

Tolstoy's Letter on the Russo-Japanese War, 1904.

From The University of Texas Mineral Survey, Austin, Texas.

Bulletin No. 9, November, 1904.

From the Boston Transit Commission.

Tenth Annual Report of the Commission, 1904.

THE ENGINEERS' CLUB OF PHILADELPHIA,

House, No. 1122 Girard Street,

PHILADELPHIA, PA.

ANNUAL REPORT OF THE BOARD OF DIRECTORS

For the Fiscal Year 1904

JANUARY 7, 1905.

TO THE ENGINEERS' CLUB OF PHILADELPHIA:

In compliance with the requirements of the By-Laws, the Board of Directors offers the following report for the year ending December 31, 1904.

Eighteen regular meetings of the Club were held, at which the maximum attendance was 155, and the average 88. The increased average attendance for 1904 over 1903 is about 4 members. Ten stated and 2 special meetings of the Board of Directors were held.

Twenty-one active, 6 junior, and 3 associate members were elected; 1 active and 1 associate reinstated; 16 active members resigned; 10 active, 1 junior, and 1 associate were dropped from the rolls; 15 junior members were transferred to the active list.

The record of deaths is:

E. K. Landis, Active Member, died January 15, 1904.
E. Percy Teal, Active Member, died April 14, 1904.
C. P. Weaver, Associate Member, died May 3, 1904.
Wm. H. Nauman, Active Member, died June 15, 1904.
Henry I. Snell, Active Member, died October 20, 1904.

		1903.			1904.	
Class.	*Resident.*	*Non-Resident.*	*Total.*	*Resident.*	*Non-Resident.*	*Total*
Honorary	2	5	7	2	5	7
Active	336	116	452	341	118	459
Junior	16	4	20	8	2	10
Associate	18		18	20		20
	372	125	497	371	125	496

The following papers have been presented:

January 2d.	Concrete: Its Properties and Applications. Topical Discussion. Edgar Marburg, Charles M. Mills, Henry H. Quimby.
January 16th.	Address of Retiring President. Some Early Engineering Works in Pennsylvania. Edwin F. Smith.
February 6th.	Some Notes on Burning Bituminous Coal. John M. Hartman.
February 20th.	Reinforced Concrete in Building Construction. Emile G. Perrot.
March 5th.	Conflagrations in Cities. Topical Discussion. Henry Leffmann.
March 19th.	Recent Steam Turbine Developments. W. L. R. Emmet.
April 2d.	Failure of the Oakford Park Dam at Jeannette, Pa. Harrison Souder.
April 16th.	The Lower Roxborough Preliminary Filters. P. J. A. Maignen.
May 7th.	Sterilization of Water by Ozone. A. Vosmaer.
May 21st.	Recent Sewer Construction by the City of Philadelphia. C. H. Ott.
	Individual Operation of Machine Tools by Electric Motors. Charles Day.
June 4th.	Notes on the Use of Lutes. S. S. Sadtler.
	Recent Developments in the Diesel Engine. John D. Macpherson.
September 17th.	George Washington, Engineer. Henry Leffmann.
October 1st.	Some Causes of Fires. Washington Devereux.
October 15th.	Use of Wooden Stave Pipes for Conduits. John Birkinbine.
November 5th.	Comprehensive Park System for Philadelphia. George S. Webster, Andrew Wright Crawford, Frank Miles Day, Leslie W. Miller.
November 19th.	Modern Electric Drives. E. L. Walker.
December 3d.	The Fremont Method of Determining the Fragility of Iron and Steel. Thorsten Y. Olsen.
December 17th.	Notes on Coolgardie Water Supply. Thos. C. McBride.
	Note on the Summation of Stresses in Certain Structures. Carl Hering.
	Notes on Stresses in Wooden Stave Pipes. Silas G. Comfort.
	Engineering and Other Features of the British Occupation of Philadelphia in 1777 and '78, from the Journal of Captain John Montresor, Chief Engineer of America. John C. Trautwine, Jr.
	Numerical Illustrations of Principles Involved in the Wooden Stave Pipe Problem. Walter Loring Webb.

Members and their friends visited and inspected the Lower Roxborough Preliminary Filters on April 16th, as arranged by the Information Committee.

The Library Committee reports that the Library has been completely reclassified and indexed, and requests that the members of the Club assist in the purchase of new books by making recommendations to the Committee.

An electric switch, presented by Mr. W. M. Webb, was placed in the auditorium. A photograph of the new stone bridge of the Pennsylvania Railroad over the Susquehanna River at Rockville was presented by Mr. Joseph T. Richards, Chief Engineer, Maintenance-of-Way, Pennsylvania Railroad Company.

The furniture and fixtures of the house are in excellent condition.

FINANCIAL STATEMENT.

Receipts.

Initiation fees	$150 00
Dues for years previous to 1904	385 00
Dues for 1904	4700 00
	$5235 00
From other sources:	
Proceedings	258 10
Directory and advertisements	725 00
Interest and incidentals	87 22
Dues of 1904 prepaid in 1903	705 00
Total	$7010 32

Expenditures.

House	$1770 87
Proceedings	1360 90
Directory	283 00
Library	102 16
Information	72 20
Office	585 27
Salaries	1830 00
Luncheons	791 00
	$6795 40
Excess of receipts over expenditures	214 92
Total	$7010 32

1903 dues remaining unpaid	$40 00
1904 " " "	555 00
1905 " prepaid in 1904	595 00

Net Expenditures for 1904.

House	$2528 50
Proceedings and Directory	660 80
Library	102 16
Information	72 20
Office	585 27
Salaries	1830 00
	$5778 93

Assets, December 31, 1904.

Furniture and fixtures, as per appraisement February 17, 1900, with subsequent additions	$1947 26	
Library, as per appraisement February 10, 1900, with subsequent additions (including ten complete sets of Proceedings of the Club)	2360 56	
Total furniture and library		$4307 82
U. S. Bond, issue of 1898 (par $500), market value		522 50
On deposit, bearing interest at three per cent.		578 43
On deposit, bearing interest at two per cent. (including $595 dues for 1905)		839 09
		$6247 84

The Club has no Liabilities.

The Board congratulates the Club on the further increase in the average attendance at the meetings.

Owing to the congestion in the Club House on meeting nights, earnest efforts, as yet unsuccessful, are being made to find more commodious quarters which will not exceed the financial abilities of the Club. Alterations in the present Club House were also considered, but were abandoned owing to the short-term lease.

Respectfully submitted,

Carl Hering, *President.*
J. O. Clarke, *Secretary.*

Report of the Treasurer for the Fiscal Year 1904.

Receipts.

Initiation fees (30)	$150 00	
1890 dues	5 00	
1891 dues	5 00	
1902 dues	30 00	
1903 dues	345 00	
1904 dues	4700 00	
1905 dues	595 00	
		$5830 00
Proceedings:		
Advertisements	335 00	
Sales	105 60	
Reprints	152 50	
		593 10
1904 Directory		390 00
Interest on deposits		38 85
Interest on investment		15 00
Telephone		8 12
Billiards		15 05
Lantern slides		10 20
Total receipts		$6900 32
Cash balance Dec. 31, 1903		1312 60
		$8212 92

Expenditures.

Salaries:		
Secretary	$240 00	
Treasurer	60 00	
Clerk	960 00	
Janitor	570 00	
		$1830 00
House:		
Rent	$1150 48	
Coal	108 30	
Gas and electric light	107 07	
Ice	39 70	
Supplies and repairs	158 85	
Telephone	194 47	
Insurance	12 00	
		1770 87
Office expenses		585 27
Proceedings		1360 90
Information Committee		72 20
Library		102 16
Luncheons		791 00
1904 Directory		283 00
		$6795 40
CASH BALANCE, DEC. 31, 1904,		**1417 52**
		$8212 92

Respectfully submitted,

Geo. T. Gwilliam, *Treasurer.*

Philadelphia, January 4, 1905.

We have examined the books and accounts of the Treasurer, compared them with the original vouchers, checks, and bank books, and found them to correspond with the Treasurer's statement submitted above.

W. P. Dallet,
H. W. Spangler,
Rich'd L. Humphrey, } *Auditors*

January 14, 1905.

Carl Hering

Twenty-seventh President of the Club. January 16, 1904—January 14, 1905.

Editors of other technical journals are invited to reprint articles from this journal, provided due credit be given the PROCEEDINGS.

PROCEEDINGS

OF

THE ENGINEERS' CLUB

OF PHILADELPHIA.

ORGANIZED DECEMBER 17, 1877. INCORPORATED JUNE 9, 1892.

NOTE.—The Club, as a body, is not responsible for the statements and opinions advanced in its publications.

Vol. XXII. APRIL, 1905. No. 2

ADDRESS BY THE RETIRING PRESIDENT.

CARL HERING.

Delivered January 21, 1905.

THERE is an unwritten law, which applies in a great variety of cases, to the effect that it is when all appears to go well that seeds of trouble have opportunity to germinate and to take firm root unnoticed. It is the man who is enjoying good health, rather than the more careful invalid, who is suddenly surprised to find that unsuspected ills have gained a hold upon him. It is when machinery runs faultlessly that defects have a better opportunity to develop unnoticed to a more serious degree than when, on account of known dangers, it is scrutinized more carefully. The healthy man, if wise, will consult his physician while he is well, thereby guarding against the development of ills, instead of waiting until they have developed unnoticed to such a degree that treatment becomes imperative. We might well take a lesson from the so-called semibarbarous Chinese, who, it is said, pay their physician while they are well, and not while they are sick, thereby giving more encouragement than we do to prevention as distinguished from cure. The careful engineer in charge of running machinery will look after his oil-cups, bolts, wear, alinement, leaks, etc., as conscientiously while it is running well as when reasons for suspecting faults exist. He should take greater pride in preventing faults than in his ability to repair his machinery after they have become serious.

Notwithstanding the apparent wisdom of such a course, there is often a strong tendency, prompted by human nature, to yield to the maxim to "let well enough alone." It is sometimes argued that because we have inherited the results of the neglect of our predecessors, we should pass ours on to our successors, which has the advantage, at least, of being the simplest, easiest, and least troublesome for us. The old maxim that we should not cross bridges until we get to them is often improperly extended to include our unconcern as to whether the bridges are there, should we have to come to them, a danger which, literally taken, appeals perhaps most strongly to military engineers. The remark of a certain great general, "In times of peace prepare for war," would not have become a proverb if it did not express an important maxim.

The unwritten law referred to applies with equal and perhaps even greater force to societies, clubs, and similar organizations. It is when everything appears to be going normally that the careful scrutiny of the management is apt to slacken. It is then that the seeds of future troubles germinate and take such firm root unobserved that they become very difficult to eradicate when discovered, while if they had been noticed when still in embryo, their growth could easily have been prevented. Many of our older members will recall that the life of our own Club was in great jeopardy, about a dozen years ago, when it passed through just such an experience. Everything appeared to be going normally, and we were supposed to have several thousands of dollars to our credit and to be prospering. There was, therefore, no concern about the management, and scrutiny slackened, until it was suddenly discovered that for years the real expenditures had exceeded the real income, and instead of our having several thousands of dollars "to the good," we were greatly in debt. An examination showed that nearly a hundred members were being carried on the rolls who were not paying dues, some having resigned years before. It was only through the hard and unselfish labor and generous financial assistance of a few members who had the welfare of the Club at heart, that the organization was again placed on a self-supporting basis several years thereafter. No one will deny that it would have been far less trouble, and the effect on the Club less serious, to have prevented this crisis, instead of repairing the damage done by it.

There is still another danger in "letting well enough alone." In the present time of continued progress, if an organization like this Club keeps on the same level, it is, in fact, retrograding, when com-

pared, as it must be, with other organizations which are growing. More is expected year after year, and if it is not provided, members will become dissatisfied. Progress is, therefore, essential to normal growth, but it also shares the quality with most other good things—that it may be overdone. Revolutionary progress is apt to change the complexion of a society, and thereby may displease those who have been satisfied with the past. A too rapid, forced progress by an overambitious administration is apt to be followed by a reaction, or at least an unfulfilled expectation that it should continue for years, either of which brings disappointment with it.

An incoming administration in our Club is composed of nearly 50 per cent. of new officers, and therefore has not the advantage, in entering upon its duties, of a thorough knowledge of the affairs and of the working machinery of the management of the Club, and has no sooner become familiar with it, and is better able to direct, when the reins are passed over to the succeeding administration, which passes through a similar period of instruction.

It, therefore, seemed to your retiring President that the occasion of this address on leaving the chair was not an unfitting one to review the past history and experience of this Club, which is now enjoying a period of prosperity; to call attention to some of the things the past seems to have taught; to consider what, in his opinion, are the present needs; and to point out the directions in which further progress and development seem to be desirable and possible, basing these suggestions on the experiences not only of this Club, but also on those gained in the administration of kindred associations with which your President has been connected. The prosperity of a Club like this depends greatly on the interest taken in it by its members—on the club spirit. It was thought that this very desirable spirit might best be developed by acquainting the members with their own Club, and it is hoped that the object sought warrants bringing before you on this occasion matters which would otherwise be devoid of interest, and are perhaps more in the nature of a report than of an address.

To appreciate the lessons taught by the past, to avoid a repetition of mistakes, and to guide us in finding what should or should not be done in directing the affairs of the Club in order to maintain and increase its present prosperity, there seems no better method than to study the past records of the Club, both of the distant and of the near past, though chiefly the latter. To facilitate doing this, the accompanying uniform tables and curve sheets have been compiled from

the heterogeneous and scattered published records, from its birth to the present time, showing in very condensed and comprehensive form the past history of the Club, its growth, its successes, and its failures, and in many cases the reasons therefor. These data are highly instructive, and, in the opinion of the writer, should have been compiled long ago. As the curves are more comprehensive than the tables, and, it may be said, expose the hidden secrets of tabulated figures, let us examine them briefly, leaving the tables as the reference record.

In general, they show a decided wave form, alternate rises and falls, which seem to bear out the contention made above that, during periods of prosperity (or perhaps only apparent prosperity), the care and scrutiny which gave rise to it is apt to slacken, resulting in a downward tendency which is not noticed until it becomes very apparent; another energetic effort is then made, economy is forced upon us, and there is another rise, which is likely to be again followed by a further fall. It will hardly be denied, however, that, aside from the interests of the doctors, it is better to keep well than to be cured of ills, and this seems equally true of a Club like ours. It is claimed that such ups and downs teach us lessons. That is true, but is not the experience of others, or of the past, cheaper to us than our own or that of the present?

But in spite of these waves, most of the curves show a very gratifying and healthy general tendency in the proper direction; they show that the Club is prospering and growing, and that it now stands on a firm financial foundation; they also show that these waves are diminishing in amplitude.

The curve of membership (Fig. 1; see also Table I) shows a phenomenal increase for the first eleven years of the Club's life, reaching the record figure 512. But, unfortunately, much of this increase was spurious, and even worse. The Club had been managed almost entirely by one man, a well-paid and well-meaning official, the Board of Directors being largely a mere formal body. His maxim was a large membership at low dues. The result was that for about seven years we carried on our list, at considerable expense, a large number of "elected" members who either never joined or were in arrears for many years or had resigned or had even died, yet the notices and "Proceedings" were being conscientiously mailed to their last known addresses.

The purging, by an energetic Board, which followed the discovery of the true state of affairs, was a severe test of the strength of the

Club. The phenomenal increase in 1884–85–86 was to a considerable extent counteracted by the dropping of as many as 87 members in

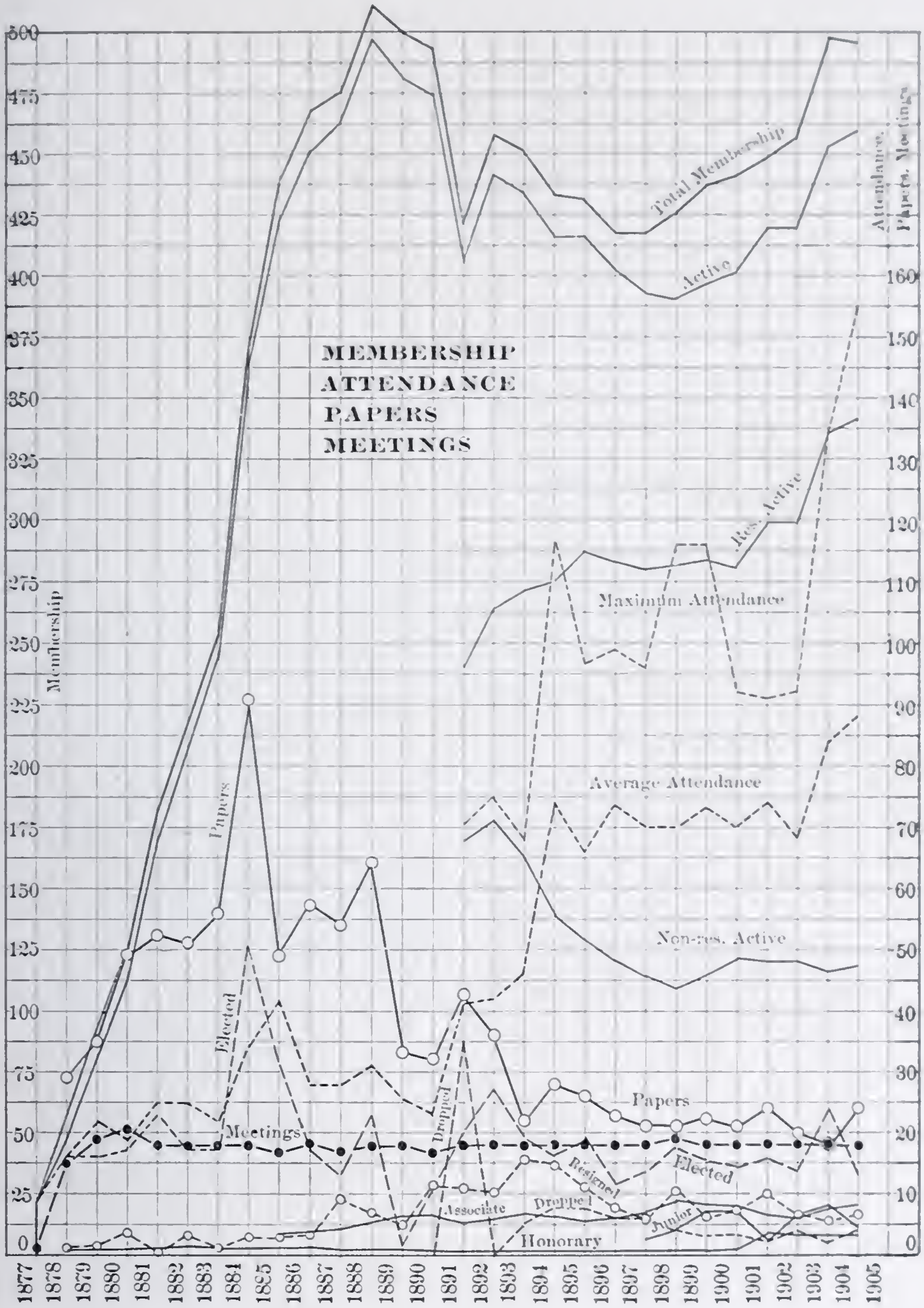


Fig. 1.

one year—1891. A subsequent slackening of the good work of the energetic Boards, aided, doubtless, also by the hard times of the early nineties, resulted in a still further decrease, but since 1896

the upward growth has been a steady and healthy one, nearly reaching the 500 mark, and establishing a high-water mark of real members, that of 1888 having been a spurious one. The present membership, 496, is well above the average of 400.

Another feature of note is the almost unbroken rise of the *resident* membership since 1891, while the non-resident steadily diminished, and for the past eight years has remained practically constant. This means that our Club is growing to be more a local one, which may not be a fault; but perhaps it also indicates that our "Proceedings" lack the attractiveness of the meetings. The resident active members now number about 70 per cent. of the total membership.

For the past twelve years the number of members elected annually has been fairly steady, averaging 40, or about 9 per cent., as compared with 46 for the whole life of the Club, and a maximum of 129 in 1884. The exceptional rise during 1903, namely 60, was unquestionably due largely to our memorable anniversary banquet. The importance of such events of special interest in making the Club known among engineers, and in increasing its membership and attractiveness, cannot be emphasized too much. It would undoubtedly be a benefit to the Club to have a prominent event of some kind each year. A banquet now and then, perhaps tendered to some prominent non-resident engineer, would do much toward bringing the Club into greater prominence, and ought to be little or no expense to the Club.

We have held several functions to which the ladies were invited, whereby social intercourse was encouraged. These meetings were very successful and might to advantage be held more frequently than in the past.

It was recently suggested by one of our prominent members that there should be an album in the Club containing the photographs of the members. This would be very useful in many ways, besides being interesting. It is said that a local photographer has offered to make these free to the Club, an offer that seems to be worthy of consideration.

It seems important that some official action should be taken to increase the number of new members in order to replace the natural annual loss and to keep the membership on the increase. The most effective work could be done by the individual members, many of whom probably have a colleague or friend among their professional associates who would be eligible to membership, and would join the Club if his attention were called to it. A special committee could also do effective work. The standing committee on membership is not

the one to do this; its duty is to pass upon the eligibility of candidates, and to solicit applications would be to anticipate its decisions on eligibility.

The lists of members of the national engineering societies show that there are many who reside in or near this city, but are not yet members of this Club. Last year committees were appointed, one for each national society, to call their attention to the advantages offered to local engineers by this Club, but the desired result was not accomplished. The impression should not be allowed to arise that the Club is in great need of new members, as this is not the case; our overcrowded meetings point rather to the advisability, before long, of establishing a waiting list; but, like in all other similar organizations, each member will receive greater benefits the larger the membership. A rapid increase would hasten the securing of the much-needed larger and more commodious home. All the prominent engineers of this district should belong to the Club, which should be the local clearinghouse for their papers and opinions. This Club should be the place where all the important engineering work in this neighborhood, and especially of this city, should be first described and discussed.

The small number of non-resident associate members has diminished steadily, and for the last few years we have had none at all. This seems to be due to the fact that the dues are as high as for resident active members. It would seem more just to reduce them to those of the other non-resident members, namely, $5; in fact, this seems imperative if we wish to keep up this class of membership.

The number of resignations has kept fairly steady for the last nine years—at 17 to 18, which is only 4 per cent. The number dropped has varied but little from nearly 8 annually for the past seven years, amounting to less than 2 per cent. The average total annual loss for the past seven years is 29, or 6.5 per cent., as compared with an average gain of 40, or 9 per cent. For the whole life of the Club the average annual loss has been 28, as compared with a gain of 46. Of all the 1250 members elected during the twenty-seven years' life of the Club, almost exactly 40 per cent. are still members, showing long terms of membership, which speaks well for the Club.

It is an interesting feature of our membership that relatively many members, namely, 79, or 16 per cent., of our present list, have retained their membership continuously for twenty years or more, including even 4 of the original 19 who founded the Club, and 6 others, making 10, who were virtually its organizers. The following is a list of these:

it was compiled with the thought that its publication might encourage the spirit of long membership. The names have been arranged and numbered in the order of their date of election.

List of Those Who Have Been Members for Over Twenty Years.

1. Billin, Chas. E., Dec. 17, '77, Chicago, Ill.
1. Lewis, Wilfred, Dec. 17, '77, Phila.
1. Muckle, Jr., M. R., Dec. 17, '77, Phila.
1. Neilson, Wm. G., Dec. 17, '77, Phila.
2. Webster, Geo. S., Jan. 18, '78, Phila.
3. Hering, Rudolph, Feb. 2, '78, New York City.
3. Lehman, A. E., Feb. 2, '78, Phila.
3. Morris, Henry G., Feb. 2, '78, Phila.
3. Potts, Wm. M., Feb. 2, '78, Wyebrooke, Pa.
3. Stauffer, D. McN., Feb. 2, '78, New York City.
4. Warren, B. F., Feb. 16, '78, New York City.
5. Cooper, Wm. A., Mar. 2, '78, Conshohocken, Pa.
6. Haupt, H., Apr. 6, '78, Washington, D. C.
7. Townsend, J. W., Oct. 5, '78, Phila.
8. Codman, John E., Jan. 18, '79, Phila.
8. Cramp, Chas. H., Jan. 18, '79, Phila.
8. Wharton, W. Rodman, Jan. 18, '79, Phila.
9. Gest, Alex. P., Mar. 1, '79, Lambertville, N. J.
9. Sheafer, Arthur W., Mar. 1, '79, Pottsville, Pa.
10. Edwards, J. Warner, Oct. 4, '79, Aspen, Col.
11. Chance, H. M., Dec. 6, '79, Phila.
12. Osborne, John G., May 1, '80, Radford, Va.
13. Reeves, David, Oct. 2, '80, Phila.
13. Smith, T. Carpenter, Oct. 2, '80, Phila.
14. Hoopes, John J., Oct. 16, '80, Greenville, Miss.
14. Kneass, Strickland L., Oct. 16, '80, Phila.
15. Johnson, Jos., Dec. 4, '80, Phila.
16. Ehlers, Peter, Mar. 5, '81, Phila.
17. Constable, Stevenson, Apr. 2, '81, New York City.
17. Ludlow, Edwin, Apr. 2, '81, Las Esperanzas, Mexico.
18. Dawson, Edwin F., May 21, '81, Phila.
18. Luders, H. C., May 21, '81, Phila.
18. Roberts, Thos. A., May 21, '81, Renovo, Penna.
19. Geer, H. M., June 18, '81, Ballston Spa, N. Y.
20. Smith, Edwin F., June 28, '81, Phila.
21. Cassatt, A. J., Nov. 19, '81, Phila.
21. Paddock, F. L., Nov. 19, '81, Bryn Mawr, Pa.
22. Clement, F. H., Jan. 14, '82, New York City.
22. deMagalhaes, A. C., Jan. 14, '82, Phila.
22. Hering, Carl, Jan. 14, '82, Phila.
22. Janvier, Thos. G., Jan. 14, '82, Lansdowne, Pa.
23. Derbyshire, Wm. H., May 6, '82, Chambersburg, Pa.
23. Gray, Wm. J., May 6, '82, Phila.
23. Jones, Washington, May 6, '82, Phila.
23. Rea, Sam'l, May 6, '82, Phila.
23. Wetherill, W. C., May 6, '82, Denver, Col.
24. Fuller, Allen J., July 1, '82, Phila.
25. Gwilliam, Geo. T., Dec. 2, '82, Phila.
26. Hutchinson, Edwd. S., Apr. 7, '83, Newtown, Pa.
26. Little, J. Kay, Apr. 7, '83, Phila.
27. Spangler, H. W., Dec. 1, '83, Phila.
28. Cresson, Geo. V., Jan. 12, '84, Phila.
28. Hartley, Henry J., Jan. 12, '84, Phila.
28. Linton, Harvey, Jan. 12, '84, Altoona, Pa.
28. Ott, C. H., Jan. 12, '84, Phila.
28. Trautwine, John C., Jr., Jan. 12, '84, Phila.

29. Christie, James, Mar. 15, '84, Pencoyd, Pa.
29. Lesley, R. W., Mar. 15, '84, Phila.
29. McKee, Jos. J., Mar. 15, '84, Bethlehem, Pa.
29. Rowbottom, James, Mar. 15, '84, Newport News, Va.
29. Wharton, Wm., Jr., Mar. 15, '84, Phila.
30. Hunter, W., Apr. 19, '84, Phila.
30. Luders, Theo. H., Apr. 19, '84, Phila.
30. Marshall, Sam'l. R., Apr. 19, '84, Phila.
30. Nute, John W., Apr. 19, '84, St. Louis, Mo.
31. Converse, John H., May 17, '84, Phila.
31. Henszey, Wm. P., May 17, '84, Phila.
31. Stevenson, A. A., May 17, '84, Burnham, Pa.
32. Chamberlain, E., June 21, '84, Norristown, Pa.
32. Dechant, Wm. H., June 21, '84, Reading, Pa.
32. Robinson, Wm. H., June 21, '84, Phila.
32. Sanne, Oscar, June 21, '84, Chicago, Ill.
33. Birkinbine, John, Oct. 4, '84, Phila.
33. Hutchinson, J. B., Oct. 4, '84, Phila.
33. Riegner, W. B., Oct. 4, '84, Phila.
34. Hill, Frank A., Nov. 1, '84, Roanoke, Va.
34. McCallum, W. H., Nov. 1, '84, Phila.
34. Wiley, Wm. H., Nov. 1, '84, New York City.
35. Newhall, Geo. M., Dec. 6, '84, Phila.

Total, 79, or 16 per cent.

The following curve sheet (Fig. 2) shows how the dates of organization and number of members of six other local engineering societies in this country compare with those of this Club. They are believed

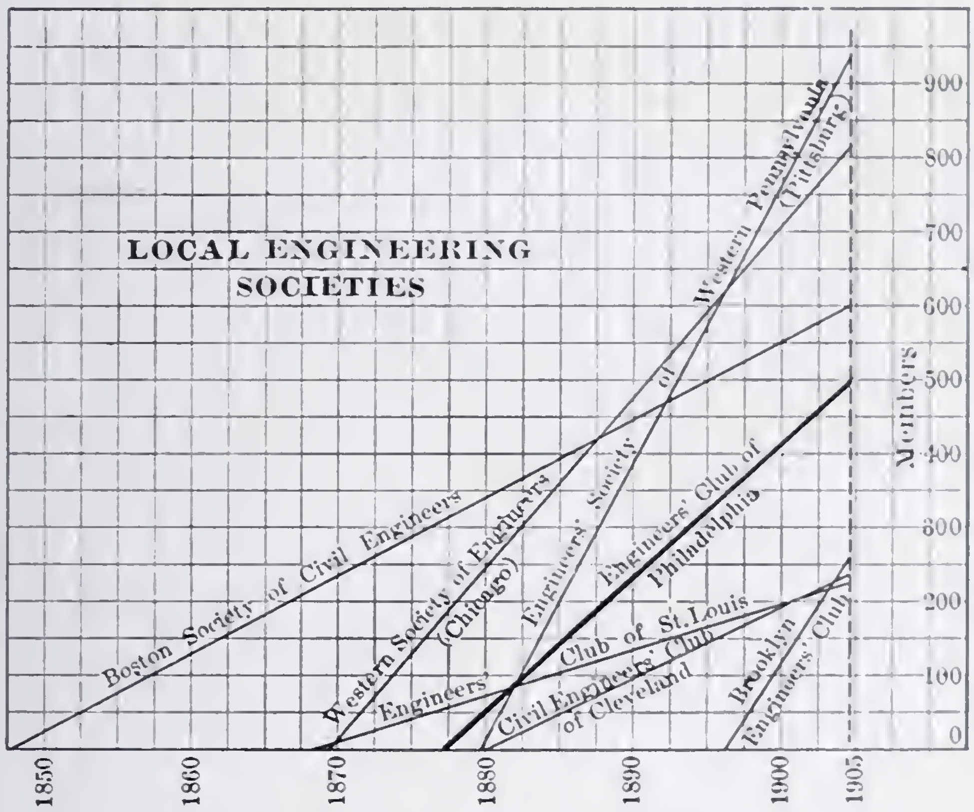


Fig. 2.

to include the largest and most prominent of these societies. The success or usefulness of a society and the benefits it gives to its members are, however, not necessarily measured by its age or size; hence

the present comparison should not be assumed to include more than these two features.

From 1890, when energetic efforts were made to increase the attractiveness of the Club, to 1895, the average attendance (see Fig. 1 and Table III) at the meetings increased very greatly—from 24 to 74, or more than trebled—thus showing what remarkably good results can be achieved by energetic management. For nine subsequent years the average remained almost steadily at 71, and in the last two years it increased to 88, all of which is very gratifying, except, perhaps, to those members who had to stand, as the attendance was often beyond the seating capacity of our meeting hall. The present maximum attendance, 155, is more than double what it was in 1891, prior to which no records were kept. This increase was especially marked during the past two years, when it rose from 92 to 155. As the membership increased far less rapidly, this shows a greatly increased interest in the meetings. These figures emphasize the rapid outgrowing of our present quarters.

The present average attendance, 88, shows that an equivalent of one in four of the resident active members, or one in about six of the total membership, attends the meetings, as compared with only one in about seventeen in 1888, when the membership was a maximum, again showing the very marked increase in the interest of the meetings, for which the Information Committee deserve our thanks.

A prominent unfavorable feature shown by these curves (Fig. 1 and Table III) is the large decrease in the number of papers, notes, and communications presented at the meetings. In the last twelve years the number has remained nearly steady at an average of 22 or 23 a year, reaching a minimum of 18 in 1903, as compared with an average of 37 for the life of the Club, and a striking maximum of 90 in 1884, the total number of papers being just 1000.

The membership of the Club includes engineers from all the different branches of engineering, besides architects, metallurgists, chemists, and men of other professions; hence to be attractive to all these varied professions the number and variety of the papers ought to be much greater than they are now. Members find too few papers a year in their own line of work. A greater variety will unquestionably attract a greater variety of members to the meetings. The number of meetings having always been about 18 a year, it follows that there ought to be more of the shorter papers and more notes and communications of interest, as there were formerly. This is strikingly shown

by the fact that the most rapid rate of increase of membership in the history of the Club, namely, 129, occurred during the year in which the number of papers was a maximum, namely, 90. From 1888 to 1896, during which the number of papers diminished greatly, the membership also diminished; in fact, this was the only period in which there was a prolonged falling off in the membership.

Among the attractions that have been greatly appreciated are the visits to places of interest to engineers. A number of these have been made and were very well attended. They ought to be continued, and, if possible, be more frequent.

Occasional exhibits of novel devices, apparatus, machines, etc., have always been appreciated, and if an abuse of the privilege is guarded against, more frequent exhibits of this kind would undoubtedly form an attraction. At this annual meeting the experiment is being tried, in a very modest form, of having a few exhibits of this kind distributed about the rooms of the Club, to acquaint members with some of the new developments. If it seems to be appreciated it might be made an annual affair, and if the number of exhibits should warrant it, arrangements might be made to hold the next annual meeting in the new engineering building of the University, where there are facilities for running machinery.

The attendance at our regular meetings might also be increased by revising the rule prohibiting smoking at the meetings, now that the practice has become so general at meetings not attended by ladies. If, as is claimed, the objections are the poor ventilation and the danger to the carpet, it ought not to be difficult to meet them. The popular vote against smoking, it may be recalled, was carried by only a single vote, and a resubmission to a vote therefore seems warranted.

Printing the chief papers in advance, and then reading them only in abstract, thereby devoting most of the time to the discussion, has frequently been suggested, and it is here urged again as a very desirable feature. It is done by other societies; why not by this one also.

The change of the meeting night to some other day of the week has been brought up again. This should be decided only after a mail canvass of the resident members, as it was done before. It is too great a change to be made without careful consideration.

The total number of meetings held amounts to 486, averaging just 18 per year. Without considering the advantages of the club-house between meetings, the cost of a meeting corresponds to an average of

$242, as compared with $377 last year. But the present cost per member, namely, 76 cents, is only slightly above the average of 60 cents.

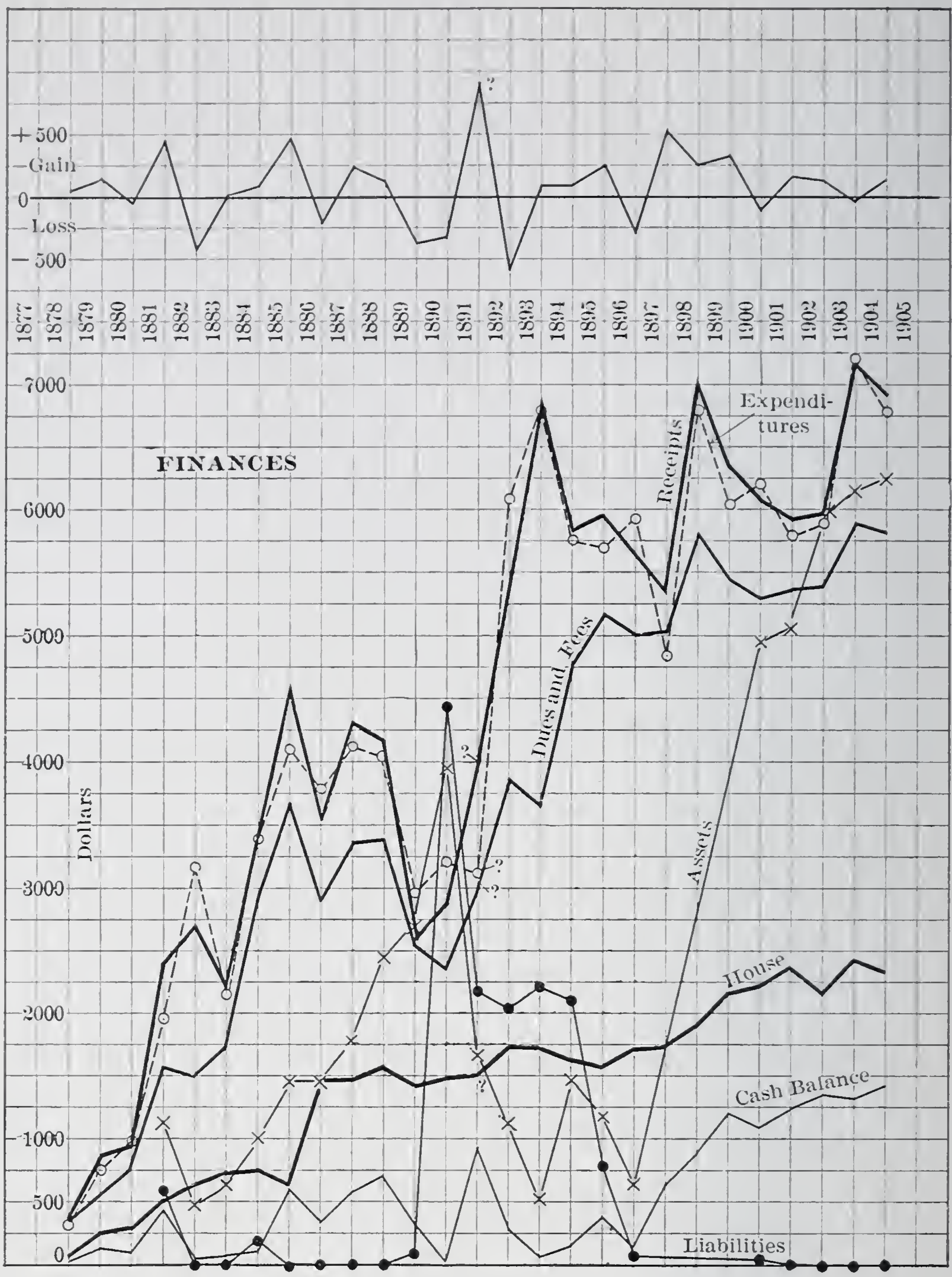


Fig. 3.

By similarly analyzing the curves showing the finances (Fig. 3; see also Table II), numerous other interesting deductions can be made, which will be very instructive to future Boards; it is regretted that

they were not at the disposal of the present outgoing Board. These deductions are too numerous to be stated here, but a few will indicate their nature. Unfortunately, the system of reporting the accounts at the end of each year was far from a uniform one, hence the apparent variations may often be obscured, but over long periods they tend to become sufficiently equal for drawing deductions. For many years your present President has urged greater uniformity, comprehensiveness, and completeness of the financial reports of the Board for each year, and he again emphasizes it now. The annual report of the Board should show the state of affairs for that year independently of the unavoidable overlappings of the two neighboring years, which latter should be eliminated from it, approximately at least.

The curves of the finances show that the receipts and expenditures have always kept together, though sometimes not very closely; but the average savings have been about $53 per year, or 1.2 per cent., on the right side, not counting the accumulating assets. The periods of excess of expenses, since the great strain in 1892, have steadily grown less in frequency and amount, and now bid fair to disappear. During the past eight years the cash balance shows a nearly steady increase, indicating a growing financial good health. During that same period the assets have increased steadily and very rapidly, while the liabilities have remained nearly at zero.

The wave form of the curves is again marked, and the present slight downward tendency should be heeded. The financial straits of 1889–90 which threatened the life of the Club, are quite marked in the curves. Besides the spurious membership, the liabilities were ignored and the assets overestimated, to try to show good annual results, which, however, were, in fact, spurious. The phenomenal recovery in the following years shows what an energetic Board of Managers is able to do. The Club owes great gratitude to the officers of 1890 and the immediately following years. The rapid rise in 1903 again shows the benefits resulting from the anniversary banquet of 1902. The marked rise in 1898 seems to have been due to an active Board, and particularly to attention to the "Proceedings."

The expenses for the club-house have increased slowly but steadily since 1885, when we moved into the present quarters.

The total expenses of the Club, amounting to about $118,000, show the average cost of a member to have been $11.30 per year, as compared with an average of $13.89 for the last ten years, and $13.67 for the past year; last year we kept within the average of the past

ten years, during which time about the same benefits were provided for members. These data are shown in Fig. 4 and Table IV for the last ten years. The total receipts of about $119,400 amount to about $11.47 per member per year, as compared with an average of $14.18 for the last ten years and $13.88 for the past year. The receipts per member last year were, therefore, below the average of the past ten years. Nevertheless, there was a gain per member of $0.21, as compared with an average of $0.29 for ten years, and $0.17 for the whole twenty-seven years.

The latter figures show a balance in the right direction, but they also show too small a margin. Our members seem to be getting too

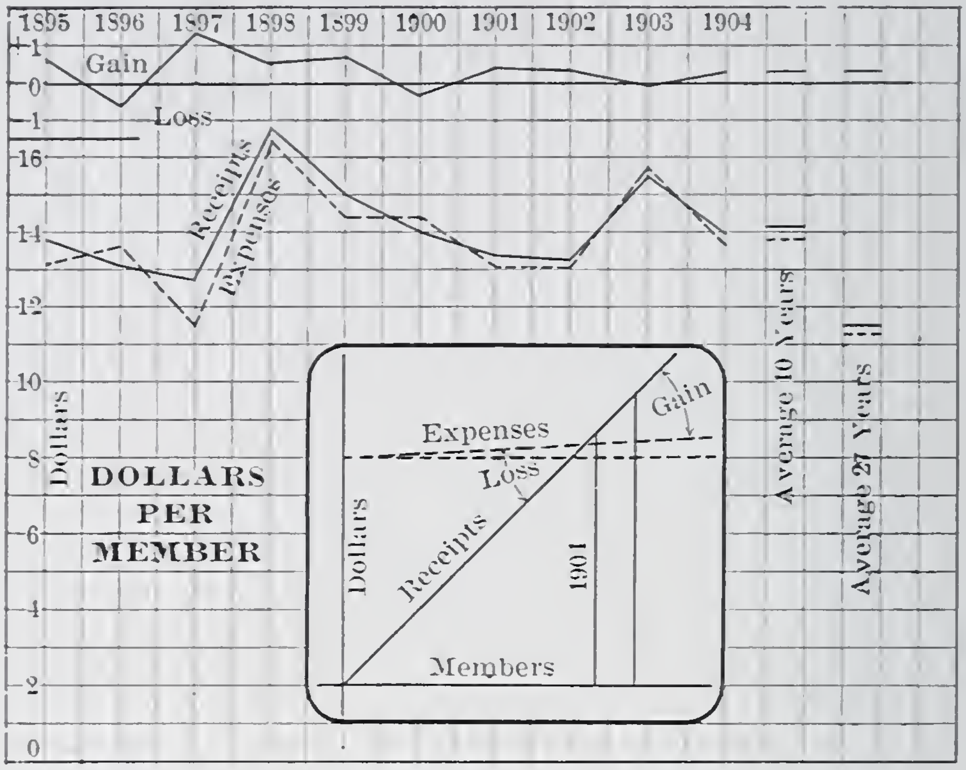


Fig. 4.

much for their dues. It is important to note, as is illustrated in the small sketch accompanying these curves, that in general the receipts of a club like ours will increase nearly in proportion to an increase of members, while the expenditures are made up of two parts, by far the larger one of which is practically constant, namely, the expenses for the house, salaries, and "Proceedings," which are practically independent of the ordinary variations in the membership; the other and much smaller part varies with the number of members. From this it follows that the gain per member increases far more rapidly than the increase in members, showing the importance of adding to our membership. On the other hand, a comparatively small decrease of

members will diminish very rapidly the gain per member, a small loss of members changing the gain into a loss. The Club has been hovering quite near this turning-point; a comparatively small increase of members would bring it to a safe distance beyond, besides yielding a much desired surplus.

One of the unfavorable features, and to which earnest attention should be given, is the almost unbroken and rapid increased net cost of our "Proceedings" during the past eight years, as shown in Fig. 5 (see also Table II), which gives the gross and net cost and income. The "Proceedings" have always been a source of expense, notwithstanding the frequent statements that they promise to become self-supporting. With the exception of an upward tendency during the past year, which may be only apparent, the net cost has been steadily and rapidly increasing. There seems to be a slow but steady increase in income during the past three years, yet the corresponding cost has increased much more rapidly. The diminution in net cost in 1896 was due to a trial to have it published free to the Club by an advertising agency; this seems worthy of reconsideration.

The "Proceedings" have cost us $23,870 for 21 volumes, averaging $1137 per volume, or $284 per issue, as against an income of only $14,749, averaging $702 per volume, or $175 per issue, leaving a total loss of $9121, or $434 per volume, and $108 per issue. This amounts to nearly $1 per member per year. During the last year the total cost increased to $1361, or $340 per issue, as against an income of $593, or $148 per issue, leaving a loss of $768, or $192 per issue, or over $1.50 per member per year. Although these figures are better than they were the year before, they are, nevertheless, more unfavorable than the average, the loss being nearly twice as great.

Earnest efforts ought to be exercised to make the "Proceedings" as nearly self-supporting as possible. Publishing them jointly with other allied societies might again be considered. They should also be published as promptly as possible, otherwise their value is greatly diminished, and they are our chief attraction for non-resident members. A general index for all the volumes, or for the first 20 volumes, would greatly increase their value. As some of the issues had unwisely been allowed to become completely exhausted, the value of our stock of back numbers had been reduced to almost nothing. But with a special effort made this past year a few copies of the exhausted numbers were again secured and the value of our stock has thereby been greatly increased. There are now 10 complete sets in our pos-

session. The price of these should be raised, owing to their limited number, and these complete sets should not again be allowed to be

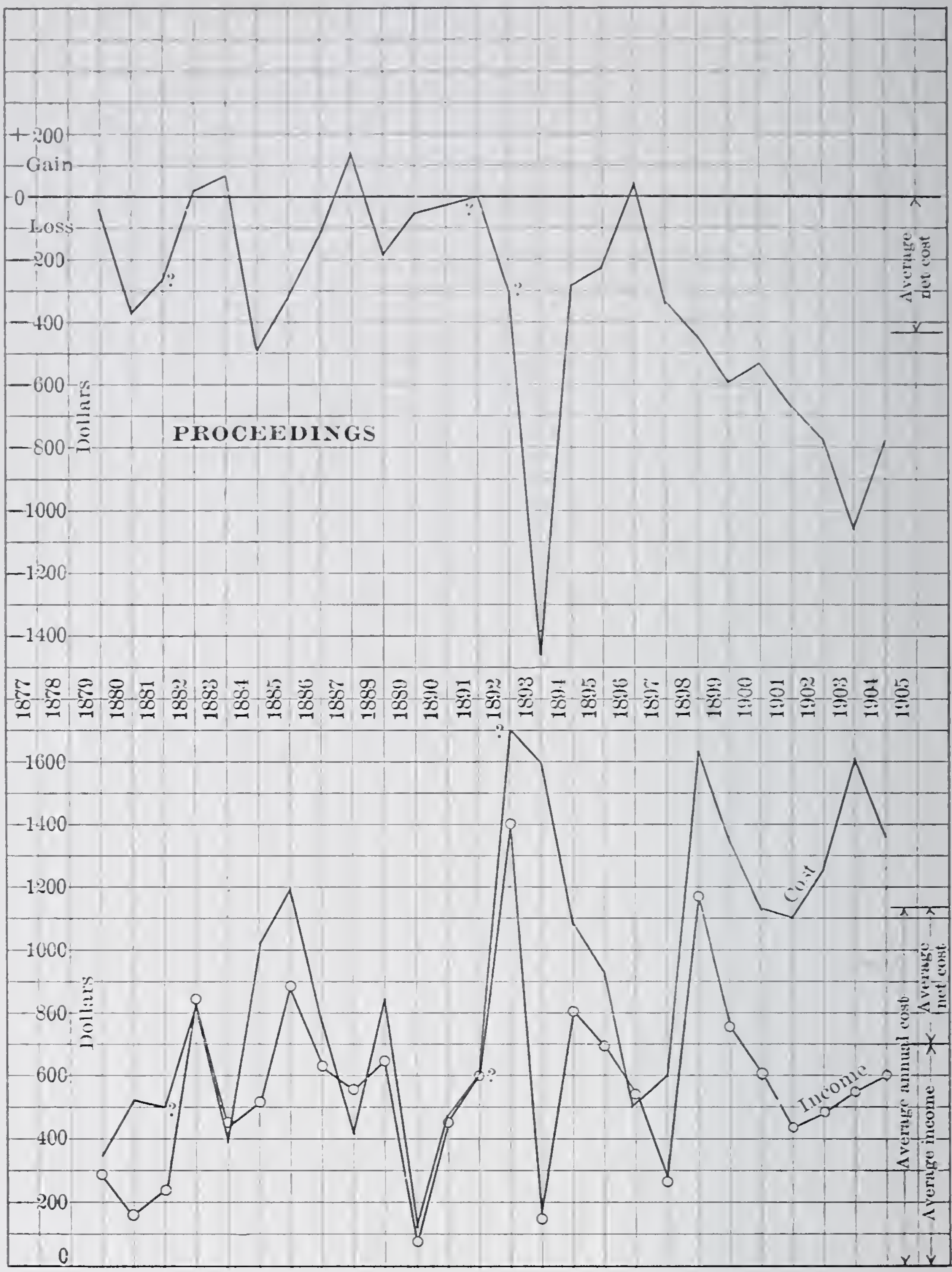


Fig. 5.

broken. By continuing these efforts a few more complete sets could undoubtedly be added to our assets.

Concerning the officers of organizations of this kind, and the methods of choosing them, experience has indicated many suggestions which

it seems wise to heed. Among these might be mentioned the following, some of which have already been followed in our Club.

The president should be chosen from those who have been members for a number of years, and have shown an unselfish interest in the welfare of the Club; he should be free from political and factional influences. In such organizations as ours, in which the proper conduct of that office requires much time and labor, experience has shown that it is dangerous to tender this highest honor to one whose brilliant achievements may give prestige to the Club, but who cannot devote the necessary time and interest to it. Or, to put it briefly, presidents who are exclusively ornamental are apt to be costly. It would be a very grave error to elect a president who has not previously served a term on the Board; the best plan would be to select him only from the past vice-presidents. We should, therefore, exercise some forethought and elect to the Board or vice-presidency the future possible candidates for this office. A term on the Board is one of the best tests of one's fitness to be placed at its head. Our invariable custom not to reëlect a president for a second, immediately succeeding term seems a good one to continue. Some weight should also be given to an adequate representation, in the chair, of the different professions composing the active membership of the Club. Our past presidents were divided as follows: 12 were civil engineers, 10 mechanical engineers, 1 a mining engineer, 1 a military engineer, 1 an architect, and 1 a chemist.

It is interesting to note that, of our 26 past presidents, the last 14 are still active members of the Club, attend the meetings, and take an interest in its welfare. Of the 12 others, 6 have died, 3 have resigned, 1 has become a non-resident, and 2 are still resident members.

Vice-presidents should be selected chiefly with a view of their becoming future presidential candidates; chance, entirely beyond our control, may make one of them our president.

The practice of intrusting the affairs of the Club almost entirely to a Board of Directors seems to have been very successful, as it leaves the meetings practically free for papers and discussions. It is the method now generally adopted by similar societies. But the success or failure of the management depends in so great a manner on the chairmen of the standing committees of the Board, that it seems important to bear in mind the nature of their duties in selecting candidates for the directors. The attractiveness of the subjects discussed at the meetings, and therefore indirectly also the growth in

membership, depends largely on the Chairman of the Information Committee. To non-resident members the attraction depends, in addition, largely on the promptness and editorial abilities of the Chairman of the Publication Committee, while the comforts and attractiveness of the club-house depend largely on the Chairman of the House Committee. Credit for successes in these directions, therefore, belongs largely to these chairmen.

It is, of course, an honor to be elected to an office of the Club, but it is a grave mistake to elect an officer merely to confer an honor upon him, as much time and labor are required of the officers.

As an outgoing Board has had a year's experience in managing the affairs of the Club, while the greater part of an incoming Board has had none, good results would be very likely to follow if it be made a rule that each outgoing Board, or the retiring President, be instructed to prepare a sort of message to the incoming Board, containing recommendations and suggestions based on the past year's experience. Such matters would then remain before the new Board and the Club, until acted upon, and that Board would then have the advantages of the experience and the opinions of its predecessor.

It has been the experience of many societies, including our own, that as much as possible of the business of the society should be intrusted to its secretary. On him, probably more than on any other single officer, does the success and growth of the Club depend. He should, if possible, be made the executive officer of the Club, and be responsible to the Club and to the Board for the duties intrusted to his care. He should be strictly impartial, and capable of being trusted not to sacrifice the interests of the Club to his own. His chief aim should be to carry out intelligently the wishes of the administrative Board, and to promote the interests and welfare of the society. A good, virtually permanent, secretary is the most valuable acquisition of a society; he can do as much good as a poor one can do injury. The growing practice of making the secretary of a society its chief executive officer, seems to be a good one, provided, however, that the Board continues to assume the responsibilities intrusted to it by the Club, even though it may have, in turn, wisely, or perhaps unwisely, intrusted them to the secretary. As the abuse of this power is a source of great danger, it must be very carefully guarded against.

Our own Club is fortunate in having in Mr. J. O. Clarke an able, impartial secretary, with discretionary power, and I feel sure that

the members of the Club and of the Board join me in greatly regretting that, owing to the lack of the necessary time to perform the duties of the office, he would not accept the renomination which was offered him.

Changing secretaries, when the office has been satisfactorily filled, is always regrettable, especially when such a large part of the Board changes each year. A secretary should be virtually a permanent officer who is quite familiar with all the affairs and past policies of the society; he should be thoroughly identified with his society. The annual reëlection to this office has, however, been found by most societies to be a wise precaution.

An energetic treasurer, like our present one, who has the interests of the Club at heart, can do much toward keeping the Club from getting into debt, and toward keeping as low as possible the annual loss due to resignations or dropping from the rolls.

There is grave danger in intrusting too much authority to employees of the Club, as distinguished from officers. They should be held strictly responsible to some one particular officer or committee, who, in turn, is responsible to the Board. He who serves many masters is responsible to none, and is tempted to become a master to himself, as this Club has found out to its regret.

According to our new method of nominating officers, their election is in effect practically in the hands of the Nominating Committee. But if there is one thing which members are apt to guard more jealously than any other, it is their right to choose their officers, and it might, therefore, perhaps be an improvement on our otherwise satisfactory system if each member be at least given an opportunity to make suggestions for nominations to guide this committee in making its selections or recommendations. The choice made by such a committee is likely to be a wiser one than that due to mere numbers of nomination votes, perhaps due to objectionable "practical politics," but members will then have had an opportunity to express their wishes, if they have any, and to have them duly considered. Dissatisfaction with the nominations of the Committee would thereby be lessened. Analogous systems are used in other large societies, apparently to the general satisfaction of all concerned. It has also been suggested several times that this nominating committee should be instructed, or at least permitted, to nominate two candidates for one or more of the offices, leaving the final choice to the members.

The Club is to be congratulated that, with but a few exceptions,

the elections have been comparatively free from heated factional contests or objectionable political methods, which are especially unbecoming to a body of men who have, or should have, but one goal, the general welfare of the Club as a whole.

One of the most important subjects to which this Club should now give its earnest attention is that of a new and permanent home. We have unquestionably outgrown our present quarters, which we have occupied for twenty years. There have been many meetings at which quite a large number of members had to stand; in fact, during one year the *average* attendance at the meetings exceeded the seating capacity of our meeting hall at that time. Our lunch room has been totally inadequate for many years. With the utmost crowding of chairs, the erection of some benches, the utilization of the hallway, and resorting to the stairway as a gallery, the maximum seating capacity could be increased to 147, with no further standing room. For obtaining more room downstairs plans were considered for inclosing a part of the present yard for the buffet table, for taking down some of the partitions, and for changing the cellar into a basement lunch room; but our short-term lease did not warrant the Board to go to this expense.

The plan of renting a larger building like the present was also considered, but it would afford only temporary relief, and even if such a building, suitably located, could be found—which is not likely—it would involve expensive alterations, and rents are especially high now. A plan was also considered to rent rooms in a modern office building having a meeting hall which could be rented for the meetings, but it did not seem to meet with general favor.

The ideal plan of purchasing one or two buildings and altering them to suit our needs was also considered, but it involved either securing endowments, which did not succeed, or incurring a heavy debt, which was considered unwise, and would necessitate a material increase in dues, generally accompanied by a decrease in membership and greater difficulty of getting new members.

Lastly, there is another possible solution of this important question which seems at the same time to meet not only all the essential requirements, but also has many unessential but desirable features, and seems to be the most feasible, probably the least expensive, and probably the most satisfactory in every way. It is the construction of a union building or coöperative building, which is to be the joint home of a number of allied societies of this city, among the most important

of which would probably be our highly esteemed and senior sister society, the Franklin Institute of Pennsylvania.

This plan I ventured to urge in this Club a dozen years ago, but it died in the hands of an inactive and unsympathetic committee. Since that time the conditions seem to have grown more favorable to its realization. The apparent hopelessness of other plans seems to be better realized, and a similar plan has since been approved in New York city, where it is now being carried out on a very extensive scale for the large national engineering societies, and has met with such favor that it has been most generously endowed by our esteemed and eminently successful fellow engineer, Mr. Andrew Carnegie, to the extent of $1,500,000, besides numerous other large, yet relatively smaller endowments to the individual societies. Your retiring President therefore ventures to again urge that this plan be earnestly considered by this Club.

Without aspiring to anything approaching the pretentious structure in New York, which even for those large societies may for a time be a heavy though willingly carried load to bear, the more modest proposition in its different forms is about as follows: In its ideal form it would be to have a sufficiently large, modern, fire-proof building, centrally located, with one large and one smaller lecture hall, well equipped for scientific lectures and meetings, and supplied with electric current and power. These halls would be used in turn by all the participating societies, thereby saving to each society the relatively great expense of an inadequate hall of its own, which remains unused during by far the greater number of days in the year, as is the case with this Club. Such halls might also yield a revenue by being rented to others than the tenants.

The large and exceedingly valuable technical library and historical relics of the Franklin Institute would be in a strictly fire-proof part of the building, with suitable reading-rooms. It might have adjoining alcoves containing the less pretentious libraries of the other societies under joint management. Each participating society would have its own conversation rooms and executive offices. A restaurant, either exclusive or public, would be a very desirable feature; it would facilitate the providing of our after-meeting lunches, and would, no doubt, increase the daily intercourse between engineers at their noon lunches and dinners, and provide an attractive place to entertain visiting engineers, especially if provision could be made for banquets.

If, in addition, there were offices rented to engineers, and well-

lighted rooms for architects, they would doubtless be well patronized. To patent attorneys and solicitors the reference library and records of patents of the Franklin Institute in the same building with their offices would be a very attractive feature. Large engineering corporations would be likely to rent suites of rooms. To all engaged in engineering pursuits it would be very attractive to have combined, under the same roof, their own business offices, those of their colleagues and associates, the valuable reference and technical library of the Franklin Institute, the social rooms of our Club, the engineers' rendezvous in the restaurant, the facilities for receiving non-residents, and the professional food and entertainment at the evening meetings of the various societies, which would probably be offered nearly, if not quite, six evenings a week. The membership of each of the societies would be likely to increase largely as the attraction of each became better known.

Like in the building of the Engineers' Club in New York and allied societies in that city, and some in this city, the project might be extended to include lodging facilities for visiting engineers.

Besides the Engineers' Club and the Franklin Institute, there are a number of other societies who would be attracted to such a joint coöperative home of societies. Among them are the Geographical Society, the Photographic Society, the Philadelphia Chapter of American Architects, the T-square Club, the Technischer Verein, and doubtless others, besides numerous non-technical societies who would be attracted by the facilities offered to such organizations.

The cost of such a building might be provided in one of several different ways. The most desirable way, though perhaps the most difficult to accomplish, is by endowment, a great and lasting monument of some generous philanthropist. The income from the tenants would more than pay for the maintenance, the building being held in trust. The feature of business offices for engineers and others would then perhaps be excluded, but investing capital might in such a case be induced to provide for these in an adjoining building with communicating entrances.

Another suggestion, and perhaps the most feasible, was to have the largest of the societies, namely, the Franklin Institute, erect and own the building, investing its endowments in it and realizing its income from the rents of the other tenants. If mortgage bonds are necessary at first, they could be purchased later by that Institute, as it receives endowments in the future which its increased prominence would then be more likely to induce.

Failing this, another method would be a purely coöperative plan of investing the ownership in a stock company, the stock being subscribed by the renting societies and their individual members. If not constructed on an elaborate scale, such stock should pay sufficient interest to be subscribed for as an investment. Endowments of the societies could be invested in such stock. Other office buildings are remunerative investments; why should not such a one be. All the societies and engineers now pay rent, which it is to be presumed is remunerative to the respective landlords; why should it not be even more so when certain expensive parts of their homes, such as the meeting halls, are rented by all of them. For better facilities they would probably pay higher rents; reductions in cost of such items as janitor services would enable them to do so.

As a last resort, and probably the least attractive proposition, it might be possible to induce investing capital to erect such a building as a business enterprise, the societies taking long-term leases.

Under certain circumstances such a building might be exempt from municipal taxation, although there are attending disadvantages which should be carefully considered.

Among all the various propositions under consideration for a new, attractive and permanent home for the Engineers' Club, it ought to be possible to find some feasible one, and this should be done with as little delay as possible. Our Committee, under the Chairmanship of Mr. James Mapes Dodge, recently President of the American Society of Mechanical Engineers, and, therefore, familiar with the organization of the union engineering building to be erected in New York, and one of the most energetic members of the Franklin Institute, reports as follows:

"The question of new quarters for the Club has been discussed in many phases, and there is a very decided hope expressed by many that some form of union building can be arranged for, and that efforts have been made to bring about its consummation. As yet, nothing has been settled regarding the financing of such a project, though hope is entertained that the present year may develop something tangible in this line."

The Franklin Institute, under the presidency of our past President, Mr. John Birkinbine, and equally in need of a new home, is at present earnestly considering the subject. Allied societies are becoming interested in their own behalf. New York is setting the example of a union building for societies. With all this interest manifested at the

present time, it is earnestly hoped that some good result will follow, and that, in the near future, the Engineers' Club will be comfortably and permanently housed in a home befitting the good work which this prosperous Club is doing.

Before concluding, I wish to say that I had intended reviewing also the more interesting and entertaining, though less instructive, incidents in the history of this Club; but this more pleasant task has already been done in part by others,* and may be found in condensed form

Fig. 6.—North Merrick Street.

in the "Proceedings," and I will, therefore, limit myself to supplying one interesting omission before the records of it are destroyed, like the original. For this I am indebted to our past President, Mr. Joseph T. Richards, of the Pennsylvania Railroad, who, in searching for me in the archives of his company, succeeded in finding a good photograph of the former buildings on the site of which the monu-

* See Billin, vol. i, p. 1; Marburg, vol. xviii, p. 61; Lewis, vol. xx, p. 33; also in the published minutes of the Club and the Board.

mental Broad Street Station now stands, and in one of which buildings, namely, No. 10 North Merrick Street, now Broad Street, was the first home of this Club. I take pleasure in presenting a photograph of it to the Club in behalf of Mr. Richards, who had it copied for us. (Fig. 6 is a reproduction of it.)

In retiring from this chair I wish again to express my thanks and appreciation to you for the honor you conferred upon me, and for the uninterrupted courtesies shown to the chair by the members at large, and by those of the Board, during the past year. And I wish to extend to the Club my best wishes for a continuation and an increase of its present prosperity.

TABLE I.—MEMBERSHIP.

Year	At the Beginning of the Year.														During the Year.			
	Active.			Associate.			Corresponding.	Junior.			Honorary.			Total Members.	Elected.	Resigned.	Died.	Dropped.
	Resident.	Non-resident.	Total.	Resident.	Non-resident.	Total.		Resident.	Non-resident.	Total.	Resident.	Non-resident.	Total.					
1877	..	..	..	..	..	..	..	..	..	..	..	..	..	..	19*	0	0	0
1878	..	..	19	..	..	..	..	..	..	..	..	..	..	19	41	3	1	0
1879	..	..	44	..	..	..	8	..	..	..	..	..	2	54	40	3	1	0
1880	..	..	81	..	..	..	10	..	..	..	..	..	2	93	42	10	0	0
1881	..	..	113	..	..	..	9	..	..	..	..	..	3	125	59	2	1	0
1882	..	..	169	..	..	..	8	..	..	..	..	..	4	181	43	8	0	0
1883	..	..	204	..	..	..	8	..	..	..	..	..	4	216	43	3	3	9
1884	..	..	244	..	..	..	6	..	..	..	..	..	3	253	129	7	4	0
1885	..	..	363	..	..	..	5	..	..	..	..	..	3	371	79	7	4	0
1886	..	..	423	..	..	8	5	..	..	..	..	..	3	439	42	9	4	0
1887	..	..	451	..	..	9	5	..	..	..	..	..	3	468	32	23	2	0
1888	..	..	462	..	..	11	..	..	..	..	..	..	2	475	57	18	2	0
1889	..	..	497	..	..	13	..	..	..	..	..	..	2	512	3	12	4	0
1890	..	..	481	..	..	16	..	..	..	..	..	..	2	499	25	29	2	0
1891	..	..	474	..	..	17	..	..	..	..	..	..	2	493	50	27	3	87
1892	238	169	407	11	2	13	..	..	..	..	..	1	1	421	67	25	5	0
1893	264	177	441	12	3	15	..	..	..	..	..	1	1	457	49	38	4	13
1894	271	163	434	13	4	17	..	..	..	..	..	1	1	452	41	37	4	20
1895	275	140	415	13	3	16	..	..	..	..	..	1	1	432	48	28	2	19
1896	287	129	416	11	3	14	..	..	..	..	..	1	1	431	29	19	8	15
1897	282	120	402	13	2	15	..	..	..	..	..	1	1	418	34	15	4	15
1898	279	114	393	15	2	17	..	5	1	6	..	1	1	417	43	25	1	9
1899	281	110	391	20	2	22	..	9	2	11	..	1	1	425	37	14	4	8
1900	283	115	398	19	1	20	..	12	5	17	..	1	1	436	34	17	4	8
1901	280	121	401	18	1	19	..	15	4	19	1	1	2	441	39	24	3	6
1002	299	120	419	14	1	15	..	6	..	6	2	6	8	448	35	16	2	9
1903	299	120	419	14	..	14	..	12	4	16	1	6	7	456	60	13	2	5
1904	336	116	452	18	..	18	..	16	4	20	2	5	7	497	30	16	5	10
1905	341	118	459	20	..	20	..	8	2	10	2	5	7	496	..	..	..	..

* Charter members.

Table II.—FINANCES.

Year.	During the Year.								At End of Year.		
	Receipts.			Expenditures.			Gain and Loss.				
	Dues and Initiation Fees.	Proceedings.	Total.	House.	Proceedings.	Total.	Receipts and Expenditures.	Proceedings.	Cash Balance.	Assets.	Liabilities.
1878	$383	0	$383	$97	0	$359	+ $24	0	$23	. .	. .
1879	565	$295	867	241	$340	754	+ 113	— $45	136	. .	. .
1880	759	160	946	300	523	976	— 30	— 363	107	. .	. .
1881	1577	237	2423	565	500*	1946	+ 477	— 263*	463	$1125	$583
1882	1494	839	2735	656	827	3146	— 411	+ 12	52	492	. .
1883	1717	444	2178	747	395	2158	+ 20	+ 49	72	626	. .
1884	2904	520	3445	756	1012	3395	+ 50	— 492	122	1019	194
1885	3703	881	4589	640	1202	4101	+ 488	— 321	609	1498	15
1886	2906	627	3535	1476	761	3779	— 244	— 134	365	1473	0
1887	3351	560	4333	1479	422	4111	+ 222	+ 138	586	1773	0
1888	3394	646	4160	1554	842	4032	+ 128	— 196	714	2454	0
1889	2527	76	2588	1446	127	2972	— 384	— 51	331	2658	85
1890	2336	446	2884	1478	478	3196	— 312	— 32	19	3960	4437
1891	3000*	600*	4000*	1500*	600*	3096*	+ 904*	0*	923	1662	2171
1892	3854	1397	5454	1739	1700*	6078	— 624	— 303*	299	1125	2059
1893	3657	147	6858	1727	1612	6793	+ 65	—1465	65	534	2228
1894	4793	797	5828	1611	1092	5753	+ 75	— 295	140	1480	2105
1895	5183	692	5958	1576	903	5708	+ 250	— 211	390	1162	769
1896	5005	540	5650	1698	500	5927	— 277	+ 40	113	633	65
1897	5026	258	5344	1746	594	4826	+ 518	— 336	631	. .	. .
1898	5810	1182	7027	1909	1620	6782	+ 245	— 438	875	. .	. .
1899	5453	756	6373	2142	1353	6052	+ 321	— 597	1196	. .	. .
1900	5310	598	6093	2202	1131	6206	— 113	— 533	1083	4963	51
1901	5377	435	5929	2359	1105	5788	+ 141	— 670	1224	5064	0
1902	5405	479	5985	2161	1259	5867	+ 118	— 780	1342	5940	0
1903	5898	544	7144	2427	1611	7173	— 29	—1067	1313	6153	0
1904	5830	593	6900	2341	1361	6795	+ 105	— 768	1418	6248	0

* Estimated.

Table IV.—DOLLARS PER MEMBER.

Year.	Receipts per Member.	Expenditures per Member.	Gain and Loss.
1895	13.79	13.21	+ 0.58
1896	13.11	13.75	— 0.64
1897	12.78	11.54	+ 1.24
1898	16.85	16.29	+ 0.56
1899	14.99	14.24	+ 0.75
1900	13.97	14.23	— 0.26
1901	13.44	13.12	+ 0.32
1902	13.36	13.10	+ 0.26
1903	15.67	15.73	— 0.06
1904	13.88	13.67	+ 0.21
Average.	14.18	13.89	+ 0.29
" 27 years	11.47	11.30	+ 0.17

TABLE III.—MEETINGS, PAPERS, OFFICERS.

Year.	Number of Meetings.	Number of Papers.	Average Attendance.	Maximum Attendance.	President.	Secretary.	Corresponding Secretary.	Treasurer.	Annual Reports for the Year, Volume and Page.
1877	1	..	19	..	....	....	......	......	....
1878	16	29	..	..	Haupt.	Billin.	......	Billin.	I—106
1879	19	35	22	..	Clark.	Hoopes.	Billin.	"	I—282
1880	20	49	19	..	Graff.	Lewis.	Murphy.	Roberts.	II—136
1881	18	52	25	..	Kneass.	Murphy.		Murphy.	III— 38
1882	18	51	25	..	Hering (R.).	"		"	III—256
1883	18	56	22	..	Morris.	"		"	IV— 40
1884	18	90	34	..	Ludlow.	"		"	IV—383
1885	17	49	42	..	deKinder.	"		"	V—255
1886	18	57	28	..	Jones.	"		"	VI—133
1887	17	54	28	..	Cleemann.	"			VI—253
1888	18	64	31	..	Wilson.	"		"	VII—119
1889	18	33	26	..	Sellers.	"		"	VII—362
1890	17	32	24	..	Spangler.	"		"	VIII—134
1891	18	43	41	70	Lewis.	{ Murphy. Trautwine. }		Smith.	IX—169
1892	18	36	42	75	Christie.	{ Trautwine. Rondinella }		"	X—190
1893	18	22	46	68	Birkinbine.	Rondinella.		"	XI—120
1894	18	28	74	118	Trautwine.	"		Gwilliam.	XII—106
1895	18	26	66	97	Webster.	"		"	XIII— 65
1896	18	23	74	99	Falkenau.	"		"	XIV— 76
1897	18	21	70	96	Richards.	"		"	XIV—312
1898	19	21	70	116	Schermerhorn.	"		"	XVI— 61
1899	18	22	73	116	Schumann.	"		"	XVII— 43
1900	18	21	70	92	Marburg.	"		"	XVIII— 75
1901	18	24	74	91	Leffmann.	"		"	XIX—137
1902	18	20	68	92	Hartley.	"		"	XX—141
1903	18	18	84	135	Smith.	Clarke.		"	XXI— 69
1904	18	24	88	155	Hering (C.).	"		"	XXII— 83

PRINCIPLES AND APPLICATIONS OF MERCURY VAPOR APPARATUS.

F. VON KELLER (Visitor).

The term "mercury vapor apparatus" comprises all apparatus in which electric current is conducted through mercury vapor, and this conduction becomes useful in the following ways:

1. In the lamp, the current passing through the vapor produces the light.

2. In the converter, alternating current is converted into direct current.

3. In the interrupter, certain properties of the mercury vapor conduction are taken advantage of to allow or bring about periodic discharges of the current, such as is necessary in the arts of wireless telegraphy and in x-ray production.

4. A mercury vapor alternating current switch has been operated successfully for closing and opening alternating currents.

In a number of other ways the conduction of current through mercury vapor may be of importance. All mercury vapor apparatus have their main features in common. They all consist of a high vacuum container, usually glass, and two or more electrodes, one of which is in all cases metallic mercury.

I shall first discuss the mercury vapor lamp as the one which is becoming best known and most popular among mercury vapor apparatus.

Its main body consists of a glass tube, one inch wide and 45 inches long. This tube is obviously filled with luminous vapor. At the lower end of the lamp you will find a bulb—the so-called "condensing chamber." This contains the metallic mercury. Now, as you see this lamp running, the current enters through a platinum sealing-in wire at the lower end of the tube into the mercury electrode. The mercury is evaporated and the current passes through this vapor and through the tube to the upper or positive electrode, from there out and back to the supply circuit. The condensing chamber has enough cooling surface to condense superfluous mercury vapor in the lamp, and thereby it holds the vapor at a pressure at which the lamp will

operate most efficiently. The positive electrode is an iron cup in this lamp. The lamp runs at 3.5 amperes and shows about 70 volts across its terminals. The balance of the supply voltage, which is 110 volts, is taken up in a resistance in series with the lamp—that is, we have 110 volts supply, 70 volts lamp voltage, and 40 volts balance voltage. The necessity of having a balance resistance in series with the lamp is due to the fact that the lamp has a counter electromotive force, so to speak—that is, it requires a constant voltage across its terminals for a wide range in current, so that variations in line voltage must be taken care of by this balance resistance, which may limit and regulate the current strength.

A striking peculiarity of the lamp is the fact that it has a tendency to go out at frequent periods—say a couple of times a second—which makes an induction coil necessary in the circuit, which, by means of its reactive kick, eliminates all tendency of the lamp to go out.

Now, when I turn the switch off the lamp goes out, and when I turn the switch on again the lamp does not light up again by itself. It is necessary for me to pull the chain and tilt the tube until the mercury flows to the opposite end to allow the metallic mercury to bridge across the tube, thus establishing a complete circuit from the negative end to the positive end of the tube. Now, when this mercury bridge breaks, a small arc is started which, as the mercury separates further, fills the whole tube—this is the mercury vapor arc. Apparently the negative or mercury electrode—for this one is responsible for the described method of starting—is offering a considerable opposition to the passage of current until it is broken down by an arc, for otherwise the current would readily flow when throwing on the switch. This singular property of the negative electrode is, as you will later see, the fundamental principle on which the converter operates.

This lamp has a great many strong points which are making it an important factor in commercial lighting propositions. Its most obvious advantages are—

(1) Economy in power consumption. This lamp furnishes 700 c.p. of light, while its total consumption of energy, including balance resistance, is about 380 watts, or 0.55 watt per c.p. Incandescent lamps take 3.5 watts per c.p., or six and one-half times the power of a Hewitt lamp per c.p. The best arcs take, as far as I know, twice as much power per candle as a mercury vapor lamp. You can imagine what a big saving this lamp will afford, especially where a great deal of light is needed.

(2) Now consider that in many cases 700 c.p. of the mercury vapor lamp will do the work of the very many more candles of an arc, and that is on account of the diffusion of this 700 c.p. over a length of 45 inches. If you would gaze at the same amount of light you have in one of these tubes in an arc, you would readily notice the difference between the two lights. The arc would blind your eyes very much more than this does. The diffusion of light is most important in all illuminating problems, and the following data will show you what good results the lamp has furnished in several actual installations in New York city.

One of them is the storage battery hall of the New York Transportation Company. This room was formerly lighted by 14 five-ampere arcs, taking 70 amperes at 115 volts. The illumination was poor, and the fumes from the batteries interfered considerably with the proper operation of the mechanism of the arcs. It was, in fact, necessary to remove the mechanism from the hood of the lamp and place it under separate covers. Ten mercury vapor electric lamps having been installed, have not only reduced the current to one-half of that formerly required, but they have also eliminated all troubles previously experienced. The room is 302 feet long, 42 feet wide, and 20 feet high, and is now splendidly lighted at all points.

Another installation is the illumination of a large pier in New York where ships are loaded and unloaded during the night. The pier is 491 feet long, 75 feet wide, and there is a distance of 81 feet between the lamps. Six lamps illuminate this pier to such an extent that every letter and mark on every single box, even in the furthest corner, is clearly distinguishable.

A typical installation is in the press-rooms of one of the largest New York publishing companies. Here each of the big presses is lighted by one short lamp at each end of the press, the two short lamps being in series and equivalent to one long lamp in candle power and current consumption. I could mention numerous other places where mercury vapor lamps are successfully operating at the present time. The success of these installations with so comparatively few lamps lies largely in the fact that the light is so well diffused and that it casts practically no shadows.

I should like to give you some figures showing the number of lamps generally recommended for a given area.

In drafting rooms one long lamp will light about 300 to 400 square feet. In business offices one long lamp might do for 500 to 600 square feet. In factory buildings even more space may be sufficiently lighted

by one lamp. Each case of actual installation should be individually considered, for much depends upon the character of the work done, the height of room, color of ceiling and walls, etc.

(3) But there is another strong feature in the lamp which has helped to accomplish good results—its color. You may possibly take this statement with some skepticism. The color is certainly not beautiful, but it has all the elements that make it desirable for a man who wants to see, rather than to be looked at. As a matter of fact, it lacks the red rays which are the most tiring and harmful for the eyes. While it is obvious that for esthetical lighting and for matching colors the lamp is not feasible, it has conclusively been established that the color of the light is superior to the color of any other artificial illuminant known, as far as ease on the eye is concerned.

(4) A feature that will appeal to all men who have used arc lamps is the fact that the mercury vapor lamp needs no attendance whatever when once installed, as it needs no trimming, and, there being virtually no mechanism attached to it, it is not liable to get out of order. It will take complete care of itself.

The widest field of application for the lamp lies undoubtedly in the lighting of drafting rooms, offices, factories, and workshops, where a well-diffused light is needed, casting as few shadows as possible, and where the saving in power consumption is an important item; but there is another large field of application for the lamp in photographic, photoengraving, and blue-printing work. The lamp has also made it possible to take kinematographic or moving pictures of places which were previously inaccessible for this art. The superiority of the lamp in all *these* branches lies in the fact that it is rich in actinic or chemical rays, so that its apparent weak point of color or spectral composition becomes its strongest points in these fields of application. Photographers and photoengravers have rapidly become accustomed to the lamp, and many of them are using it entirely in their workrooms. This may have been sufficient to give you a superficial idea of the principles and applications of the mercury vapor lamp.

I shall now briefly discuss the principle on which the converter operates. Its work is the transformation of alternating current into direct current. As previously stated, the action of the converter is broadly based on certain peculiarities of the negative electrode of a mercury vapor container. You saw in the lamp that the tube would not light by itself when the switch was at first thrown on. It seems as though the mercury electrode had a skin on its surface, which had

to be punctured by an arc before the current could flow through the tube without obstruction. If the supply current had been turned off for only a fraction of a second, the lamp would have reëstablished its initial starting resistance, which would have necessitated a new starting by tilting. On alternating current this lamp would not have operated for the following reasons:

Alternating current is a current which changes its direction at frequent intervals, say 120 times a second, and, of course, in doing so the current passes through a zero value 120 times a second, and the lines change their polarity just as often. If we had started the lamp on alternating current by some means it might have flashed up for an instant, but would not have continued for even a second, for as the supply circuit reversed its polarity the upper electrode would have had to run as a negative with the mercury electrode as a positive relatively to it. But what was stated in regard to the initial surface resistance of a negative electrode for mercury holds true for iron, and the lamp would not have started to run on reversed current unless the upper electrode had been started as a negative by a zero arc. Thus the lamp would have gone out as soon as the current had reversed its direction. Imagine, however, that the lamp had been provided with two positive electrodes at the upper end instead of one, and that it was connected to an alternating current circuit, as shown in the chart. Let us analyze what might have taken place then.

At a given instant current may be assumed to have the direction indicated by arrow, and would thus have entered into electrode P–1, passed through the lamp and through the same resistance and inductance we had in circuit before, and out through the winding of the autotransformer back into the supply circuit. This current will continue to flow as long as the supply has the indicated polarity. As soon as the supply reverses the direction this current through P–1 will cease to flow, but there will be a new path to the current through the lamp as follows:

Current will flow to electrode P–2, through the converter, the resistance, and inductance, and through the auto-winding back into the supply circuit. Thus there will be a continuous flow of current through the lamp, which will give a steady light, similar to the direct current lamp previously discussed. Now consider the nature of the current in the resistance in series with the negative electrode. All current which is admitted through the tube has the same direction, as it is all flowing from the positive to the negative. That means we

get a direct current in our series resistance. If the supply voltage had been comparatively high, and the voltage drop across the lamp comparatively low, then the voltage across the series resistance would have been almost equal to the supply voltage, the current in the series resistance being unidirectional. This line of thought has led to the development of the converter. The converter may be a glass globe 6 to 9 inches in diameter, with two positive electrodes and one mercury puddle serving as a negative electrode. Alternating current of almost any voltage may be put through the converter, and a corresponding direct current voltage will be obtained between the negative electrode of the converter and the middle point of the transformer. The converter is so designed that the voltage drop across its terminals does not exceed 10 to 14 volts on all circuits, so that the efficiency of the total converter transformation depends entirely upon the voltages transformed. Thus the efficiency becomes very high, say 98 to 99 per cent., on the transformation into 1000 volts direct current. Remarkable it must seem to every one who considers this newly invented apparatus, with what a small and light apparatus the transformation is accomplished. Rotary converters, which are now generally used for transforming alternating current into direct current, are incomparably heavier and more complicated machines than this converter. For instance, a rotary converter for a capacity of 5 kilowatts at 500 volts weighs 1000 pounds, while the mercury vapor converters of corresponding capacity may weigh only 8 pounds. This saving in weight and material on the part of the converter is so surprising that it may occur to you to ask, "Will the mercury vapor converter replace the rotary converter?" To this question I can only answer that I do not know. The principle of the vapor converter is so broad that there is no theoretic limitation to its general use. It will operate on all possible phase combinations now used in practice—on single phase, two phase, and three phase circuits.

The mechanical problems which the practical converter has to solve are the maintenance of a good vacuum in the container and a means of dissipating the heat generated due to the energy loss in the converter. A number of converters have continually been operated with currents up to 30 amperes D. C., and these have transformed on 240 volts direct current 7 kilowatts of energy. Such a converter is about the size of a good-sized football, and does not weigh very much more. The capacity of the converter depends, unlike that of the rotary converter, virtually only on the current strength and not on the voltage

transformed. Thirty amperes is by no means the limit of current capacity, but it will have to be demonstrated up to what capacity one container is practical and whether it will be more feasible to operate a number of converters in parallel on higher currents. Alternating current is generated in a great many power plants, and transformed into direct current at the place it is being utilized. In the west and at Niagara Falls, as well as in many big cities in the world, alternating current is conducted over lines sometimes several hundred miles, and transformed into direct current to be used for lighting, for power, and for operating electric railway systems. In many cities only alternating current is available, and direct current apparatus cannot be used. By insertion of a converter a man might be able to run his direct current motor in such cases. Storage batteries are always charged with direct current, so the insertion of a converting apparatus will always be necessary where only alternating current is available. Thus you see there is a wide field which may eventually be commanded by the mercury vapor converter.

I am sorry that I am not able to demonstrate the converter to you at this time. It is not yet on the market.

The mercury vapor discharge gap, frequently called "interrupter," operates on the following principle:

As you saw in the lamp, the negative electrode opposes the flow of current until the lamp has been started. However, had the voltage across the lamp been sufficiently high, say 10,000 volts, the initial resistance would have been overcome and current would have been able to flow freely without the special starting of the lamp. Now it is necessary, in the production of x-rays and in wireless telegraphy, to have extremely sudden periodic discharges of current through the wave-producing apparatus, and these discharges are furnished by the insertion of a discharge gap in the circuit of the wave-producing apparatus, from an alternating current supply of high voltage. This alternating current is constantly changing, and may change from a maximum to a zero value at the rate of, say, 120 times a second. If the supply voltage is high enough, the negative electrode resistance of the discharge gap is broken down whenever the alternating current supply reaches a high value during its periodic change. The current then flows freely through the wave-producing apparatus, but ceases to flow as soon as the supply voltage has again dropped to a low value. One is surprised to find how rapidly the mercury electrode responds to these extremely rapid periodic changes of voltage, but it has been

established in a series of actual tests that the discharges through the wave-producing circuit become very sudden and highly efficient through the insertion of a mercury vapor discharge gap. The interrupter presents the following advantages over an air spark gap, which is now commonly used to produce these sudden discharges. It is not subject to any kind of deterioration, as there are no metal surfaces to corrode or to burn off. The discharge is more sudden, and there is less opposition to the passage of the current after the initial resistance has been broken down, so that the waves emitted become more distinct by use of the vapor discharge gap. This little tube prevents such an interrupter. You see it is a small glass container, which is pumped to a high degree of vacuum. Its two electrodes are both metallic mercury. It requires about 10,000 volts to break down the small space between the mercury puddles, but only about 14 volts are necessary to maintain the flow of a continuous current after the current has once been started. On shaking the mercury up in the tube you will notice that a clicking sound is emitted. This shows that there is a high degree of vacuum in the tube.

The alternating current switch is a very similar apparatus; in fact, this very tube could be used as such. One has to go to quite elaborate mechanical apparatus to allow the opening and closing of alternating current circuits of high currents and voltages. The mercury vapor switch is, compared with such mechanical switching apparatus, a very simple contrivance. Suppose this tube contained more mercury, so that in the upright position the mercury could form a bridge, making a metallic connection between the two electrodes. To connect the tube as a switch I should lead the current into one electrode and out the other. The mercury then would conduct the current through the space between the electrodes. Now, if we should want to open the circuit, we should have to tilt the tube in such a position that the mercury would sever and the bridge would break. At the instant of the break the current may have the direction from the left to the right electrode. For the instant the small vapor column will be formed maintaining the flow of current, but this conduction lasts only until the current reverses its direction, that is, perhaps one one hundred and twentieth of a second. Then the same thing takes place as in the converter and interrupter, namely, on reversal of the alternating current the initial surface resistance of the mercury is reëstablished, current ceases to flow, and the circuit is now broken finally. This little tube is not designed as a switch, but if it contained more mercury

and had heavier seals, it might do for opening and closing 30 to 50 amperes at 10,000 volts. A mechanical switch to accomplish as clean a break as this mercury vapor switch would have to have a stroke between contact points of more than a foot, would weigh very much more, and be very much more complicated apparatus. Such a switch may be designed to carry any desired current.

I have described these apparatus as mercury vapor apparatus. You will often hear them referred to as the Cooper Hewitt lamp, the Cooper Hewitt converter, and so on. Most of the principles of the mercury vapor conduction were invented by Mr. Peter Cooper Hewitt, of New York, and he was certainly the first one who made the operation of the mercury vapor lamp possible for commercial purposes. Mr. Hewitt is an inventor of exceptional creative genius, and has spent many years in careful research in the principles of mercury vapor conduction. The principles underlying the vapor apparatus are so radically new that physicists, as well as technical men all over the world, have manifested considerable interest in the problems presented, and the public is more and more taking advantage of the inventions. The concern which is manufacturing some and developing others commercially is the Cooper Hewitt Electric Company of New York.

DISCUSSION.

Henry H. Quimby.—When the mercury flows along the tube and reaches the other end, does it not form a short circuit?

Mr. Von Keller.—There is not enough mercury for that. There is only about one pound. It is contained in the condensing chamber of the lamp during the operation. The mercury evaporates and condenses on the surface of the condensing bulb, so that there is a constant pressure of vapor in the lamp at all times. The size of this condensing chamber has been the result of very careful investigation. A German professor named Aarons operated a mercury vapor lamp ten or twenty years ago, but did not have any condensing chamber to it, so the heat generated in the lamp brought the pressure of the vapor up to such an extent that the lamp would require a very high voltage to maintain current. Over a certain range of current—say, between two and four amperes—our lamp requires a practically constant voltage across its terminals. At four and one-half amperes the lamp voltage begins to rise very rapidly, for there is not enough cooling surface in the lamp to dissipate the energy corresponding to an abnormally high current of 4.5 amperes lost in the lamp.

George C. Davis.—Is there any trouble from tubes cracking?

Mr. Von Keller.—The seals are, undoubtedly, the weakest part of the lamp, and these have to be carefully designed to prevent cracking.

The degree of vacuum maintained in the lamps is a very high one. There is perhaps one one-millionth part of foreign gas in the whole lamp, compared

to the volume of the mercury vapor, and that makes tightness of the seals most important. The seals have cracked, but as the lamp stands now, they will not crack unless through overcurrent or careless handling.

W. C. L. Eglin.—How is the candle power determined? How is the converter started, and how are the lamps packed for shipment?

Mr. Von Keller.—The candle power is quite a hard thing to determine. The lamps have been measured against all conceivable sources of light—incandescent lamps, arc lamps, etc. The candle power given (700) is the measurement as against an average of arcs, incandescents, and other sources of light. I do not think there is any photometer that will give an accurate measurement of this light for absolute candle power.

The converter is usually started by tilting it until the mercury bridges across the negative and a supplementary starting electrode, connected through resistance to a positive electrode, and then opening this bridge connection. The small arc thus started allows a free passage of current between the negative and positive electrode. Starting a converter is electrically possible only when the negative electrode be broken down as such—*i. e.*, at the instant an arc is drawn between the negative electrode and the supplementary starting electrode, the current in this arc must be of such an alternation and direction as to make the negative electrode act as a negative. From this it can be readily understood that the chances of the starting by this method are at best 1 to 2. I have spoken of an inductance in series with the D. C. lamp. An inductance is also necessary in an A. C. lamp and converter. Not only does this inductance perform the function of holding the negative electrode broken down during the periodic kicks, but it also stores and supplies energy in such a way as to maintain an absolutely continuous flow of current in the converter. It may readily be seen that without the inductance current would not flow in the converter circuit during the period in which the instantaneous A. C. voltage does not exceed the necessary voltage drop across the converter—that is, during the lowest voltage period of each alternation the current would cease to flow, were it not for this inductance. Now in starting, not only must the alternation be in the right direction, but it must also occur at a period which gives the impressing voltage time enough to store a sufficient amount of energy to maintain current during the low voltage period of the alternation.

As far as shipping is concerned, the seals of the lamp are subjected to a strain during transportation by the weight and the sudden knocks of mercury against them. At the end of the lamp is a flange which prevents the mercury from running up against the seal. If there were no flange, the bang of the mercury in tilting up the lamp would be sufficient to crack the seals in most cases. The tube itself is not liable to crack from the mercury. With the amount of mercury we have at present in the lamp and the flange protection there is very little liability of cracking in shipment.

A Member.—Does temperature affect the operation of the lamp?

Mr. Von Keller.—It does to some extent. The condensing chamber is so designed as to hold the vapor pressure in the lamp at a certain value, at which the candle power is a maximum as compared with the current consumption. A low temperature (very low temperature) will cut the candle power down. The candle power increases with the pressure of vapor in the tube over a wide range

of current, so that the higher the outside temperature, the higher the pressure and the higher the candle power. We operate these lamps outdoors. I think they operate satisfactorily down to zero (Centigrade), and we have them in boiler rooms which run up to 45° Centigrade.

This special design of lamp will operate over a range from zero to 45° without any considerable variation in candle power. I believe it is understood that the lower the temperature, the less light you will get. I would like to put some of those lights out for a short while to demonstrate that they will start bluish and with a small candle power. We will have to leave them out for five or ten minutes. This is due to the low pressure—the low temperature in the lamp at the start.

Wm. McClellan.—We have experimented somewhat with these tubes at the University of Pennsylvania. They get so hot with a current of four amperes that you cannot touch them with the hand. How do you dissipate the energy when you use 600 amperes. If the lamp has normal voltage it burns just as you have described. When the lamp is turned on, the current makes a sudden jump to 12 amperes, and then falls immediately to about 3.5 amperes. If the voltage is low, say 5 per cent., the voltage seems to gradually rise as the lamp warms, and the current decreases. Suddenly the lamp goes out. At other times the voltage, after the first rush, seemed to slowly fall, and the current rise until a steady value was reached. We found, apparently, a certain critical current of about 2.9 amperes. Sometimes the current would fall to this value, and rise again, the lamp remaining lit; at other times the lamp would go out at this current. This seemed sure to happen if the lamp were cold, and usually ceased when the lamp was heated. What is the cause of this action?

Mr. Von Keller.—Had you other trouble with the lamp? Did it go out quite often.

Mr. McClellan.—Yes, it did. Moreover the lamp goes out instantly on breaking the circuit, as we found once when we had a loose connection, which caused the lamp to go out every time it was jarred.

Mr. Von Keller.—I shall have to give you a few technical points about the lamp later on. I shall now just explain this: When the lamp is started cold, the pressure of the vapor is low, and the voltage consequently being low, the resulting current is high. As the lamp warms up the pressure and the voltage across the lamp increase and the current instantly drops, but during this period there is a relatively high voltage on the positive electrode, which drops more slowly than the vapor voltage rises, so that at a certain period there is a voltage across the lamp which is higher than the final value reached. This high voltage at the period mentioned causes a decrease in current as against the final current, and on this decreased current the lamp may go out under certain circumstances. Every lamp will show this current change during the starting period, but when conditions are right, the lamp will not, under any circumstances, go out during this period, and your trouble has been due only to local difficulties in the circuit which can easily be overcome.

Mr. McClellan.—Is there any reason for a slight browning of the tubes?

Mr. Von Keller.—Yes, the candle power deteriorates somewhat. Your tube gets slightly bronzed.

The President.—What makes it brown?

Mr. Von Keller.—Probably the glass is attacked by the mercury.

H. Clyde Snook.—How long do the lamps run before they have to be renewed?

Mr. Von Keller.—There is no definite life to the lamp at all. We have lamps in the office that have been running twelve to fifteen thousand hours showing about 10 to 15 per cent. depreciation. There is no reason why the lamp should not run indefinitely. I think the way incandescent lamps are rated is this: you call the life the number of hours until the candle power has dropped down to 80 per cent. of the original value. According to that you can rate our lamps at one thousand hours. Then it will drop down 20 per cent. with some lamps. On others it will not. But unless the lamp be smashed or cracked, it will run indefinitely.

Mr. Snook.—What happens when the current goes through the lamp in the wrong direction?

Mr. Von Keller.—If both electrodes were mercury, there would not be any reason for observing a polarity on the lamp. We could run the lamp in both directions. But you will notice in this lamp a bright spot running around the surface of the mercury. That is the spot where the current emerges from the mercury. This spot is concentrated heat and iron will not stand it. The lamp will run in the wrong direction for a short while, but the positive electrode will soon give off enough gas to spoil the vacuum and to make running impossible.

Mr. Schumann.—Is the reservoir made of cast iron?

Mr. Von Keller.—No, sir, it is all glass.

Mr. Klauder.—Can that principle of converter be used to make an alternating current lamp?

Mr. Von Keller.—It has been used. The alternating current lamp gives a very steady light. The induction in series with the lamp stores and supplies energy enough to almost entirely smooth out the fluctuations of the current wave.

Mr. Klauder.—There seems to be a little pulsation which is not seen in the direct current lamp.

Mr. Von Keller.—That is on account of the spot dancing around on the negative electrode. There is no flickering in the vapor.

Mr. Snook.—When the current was low, it seemed to flicker a little.

Mr. Von Keller.—Yes, when the current is low there is enough pulsation of the current, due to the negative electrode, to be perceptible to the eye.

Mr. Snook.—Did you say anything about the energy in that 600 ampere converter?

Mr. Von Keller.—I was not talking about a 600 ampere converter; I was talking about the switch. In your switch you simply have to conduct the current through the solid mercury, while in the converter you have a different loss —a vapor resistance loss. In your switch you have only your ohmic loss. Converters have operated up to 30 amperes.

The President.—How can you get 600 amperes through the glass?

Mr. Von Keller.—We had platinum plates and big copper pieces soldered to them.

W. C. L. Eglin.—Will your switch break 600 amperes, at say 10,000 volts?

Mr. Von Keller.—I do not doubt that a switch can be built which will open

600 amperes at 10,000 volts. It has, however, never been done, as far as I know, and I should not like to say what will happen. From mere speculation I should say that the condition of 10,000 volts would not involve any more serious difficulties than a voltage of 100. As far as has been demonstrated up to the present, the negative electrode in a vapor switch is true to the principles under which it operates in a converter, namely, of having a high break-down resistance and readily reëstablishing the same at the instant the current ceases.

Mr. Eglin.—In a particularly small tube is there any danger from high voltage?

Mr. Von Keller.—There is a limit.

Mr. Eglin.—What would be the distance between the terminals in a 10,000 volts switch?

Mr. Von Keller.—We would make it probably two inches. The only thing which would determine it would be leakage of current across the glass. As far as the operation of the negative electrode is concerned, the distance between terminals has little to do with the operation.

Mr. Snook.—When the tube is cold, sometimes there are particles of mercury that seem to stick to the glass. If the switch were cold, would you have to make it considerably longer?

Mr. Von Keller.—The switch is somewhat more carefully pumped than the lamp. The switch has absolutely clean mercury, and a great deal of caution is taken to hold it clean. There is no danger from that. I have a photograph here of one of the press-rooms of the New York "Times," which is using these lamps. The beauty of using the lamps in press-rooms lies in the fact that it casts no shadows. They have not been able to use any arcs in press-rooms up to the present time. Every press you see will have incandescent lamps for illumination. The vapor lamp can be installed over the press and will cast no shadows. The New York "Times" has mercury vapor lamps and is using no incandescents whatever. The presses are very big, and are lighted by one short lamp at each end of the press. They find it a very satisfactory light, as the photograph will show.

Wm. Easby, Jr.—Is there any way of shading the lamps so as to get a more pleasing light?

Mr. Von Keller.—No; except with the particular silk I have spoken of.

Mr. Easby.—Does that cut off much of the illumination?

Mr. Von Keller.—Yes, a good deal.

Mr. Snook.—When you put that red silk over the light, I think you said it introduced some red rays.

Mr. Von Keller.—It does change the color some. [Exhibiting.] You can light the lamps now. Perhaps they are cold. It takes about two minutes for them to pick up the full candle power. It is not so intense as it will be in a short while.

Mr. Easby.—You have not installed them in any private houses yet?

Mr. Von Keller.—Oh, yes, we have—in the Astor Hotel in New York. They have them in their winter garden, in addition to the incandescent lamps. We will try the incandescents with the vapor lamps and you will see what it looks like. You have a lot of light and a very pleasing effect.

Mr. Snook.—I would like to ask about the variations in the pressure of

the vapor in the vacuum tube, and if Mr. Von Keller will tell me why this happened when I attempted to use the negative electrode resistance in one of the ordinary lamps to act as an asymmetrical resistance to cut out one wave of an alternating current curve, the maximum which I wished to cut out being about 10,000 to 15,000 volts, and that which I wished to use at a voltage from 60,000 to 100,000 volts, my maximum current being about one-tenth ampere? I think that the low current was perhaps my trouble.

Mr. Von Keller.—What happened?

Mr. Snook.—It didn't break down at all.

Mr. Von Keller.—Our data on breaking down voltages in vacuum containers are not very complete yet. A very good vacuum will break down at a higher voltage than a partial vacuum, while, on the other hand, an air-space still has a higher break-down voltage than the best vacuum. The ordinary interrupter, with about two inches between the electrodes, should break down at 14,000 to 20,000 volts cold. The break-down voltage of a lamp may be considerably higher than this. In the particular case you had there was no reason for an asymmetrical breaking down as the current will just as readily flow from the mercury to the iron as from the iron to the mercury electrode. The action may be made asymmetrical by binding a metallic band on the outside of the glass around the electrode which is to act as a negative, and connecting this band to a high voltage with respect to its negative, so that there is a condenser action taking place between the band on the outside of the glass and the mercury on the inside, resulting in small arcs, which keep the mercury surface broken down in such a way as to pass current readily in one direction. I am not ready to say whether the failure to break down in your case was due to insufficient current or to the vacuum in the lamp or other conditions.

Mr. Snook.—The breaking-down voltage of the little interrupter is perhaps 10,000 to 20,000 volts?

Mr. Von Keller.—Yes, say 10,000 to 15,000 volts. It is very sensitive to vacuum and to leakage over the glass and to the condition of the mercury surface. Clean mercury globules will be round. If there is just a slight spot on the mercury—a bit of dirt—that may decrease the initial negative electrode resistance.

Mr. Snook.—It punctures the film. Then the pressure on the gas increases immediately at the time the negative resistance is broken down, and the pressure rises to perhaps a tenth of a millimeter.

Mr. Von Keller.—Yes, possibly a little more—about fifteen hundredths. That corresponds to about 800° Centigrade on the electrode.

The President.—I would like to know how this cloth can acquire the red rays when there are no red rays in the light. When illuminated by the light, it certainly gives off red rays. Where do they come from?

Mr. McClellan.—I think it is due to the orange rays. There are no red rays in the light. I was able to find, with the spectroscope, two violets, blue, green, green-yellow, and orange-yellow.

The President.—Is that a particular kind of dye different from any other dyes?

Mr. Von Keller.—Yes; we had a very hard time in finding it.

The President.—If it does give off red rays, it must be a transformer of wave lengths, and therefore there must be a change.

Mr. Von Keller.—There is plenty of orange in the light.

Mr. Pike.—I was interested in hearing Mr. Von Keller say that the life at which the candle power would not run down more than 80 per cent. was about a thousand hours. What happens to it after the thousand hours? Does it continue to diminish in intensity, and if so, uniformly, or does it go on at the same intensity?

Mr. Von Keller.—The lamp decreases the most within the first five hundred hours. After a certain stage has been reached there is no further decrease in candle power whatever.

Mr. Pike.—At what voltage were you running the transformer that you had 30 amperes running through?

Mr. Von Keller.—We got 240 volts out of that. We had about twice 300 or 600 across the positives—300 really active and 300 being oppressed.

The President.—Even a person with very fair and clean skin, when exposed to this light, has decided blotches in the face. I notice that it is used by photographers for portrait photography. Why is it that these blotches are not seen by the camera? These photographs do not contain the blotches which we see.

Eugene D. Hays.—It is due to the red color. If you will press the hand you will notice the rush of blood.

Mr. Snook.—Do you not find a great deal of difficulty in getting the gas out of the iron electrodes?

Mr. Von Keller.—Yes; we treat the iron electrode quite carefully.

Mr. Snook.—The reason that you do not use aluminum is that it amalgamates?

Mr. Von Keller.—Yes; and the aluminum seems to burn up. We cannot use aluminum.

Mr. Snook.—Why is one side of the little iron cup bent down?

Mr. Von Keller.—That is to catch the mercury at the starting. If it were not bent, you would have to have so much more mercury in the lamp.

Mr. Foster.—We have all been interested in the paper. I move that a vote of thanks be tendered to Mr. Von Keller for his presentation of it. [Carried.]

THE TORRESDALE CONDUIT.

JOHN W. HILL,

Chief Engineer, Bureau of Filtration.

Read February 4, 1905.

[This paper was prepared upon request of the Committee on Information.]

The Torresdale Conduit, Contract No. 14, Improvement, Extension, and Filtration of the Water Supply of Philadelphia, is a large inverted siphon to conduct the filtered water from the clear-water basin at Torresdale to the pumping station at Lardner's Point. Its nominal capacity is 300,000,000 gallons a day of twenty-four hours, with a loss of head between end-shafts of 8.6 feet, and a mean velocity of flow of 5.276 feet a second.

Influent Shaft No. 1 is located 1525.5 feet south of the center line of Pennypack Street, at the Torresdale filters, and from this point the conduit proceeds upon city property, under Pennypack Creek, and through the House of Correction grounds to Holmesburg Avenue; then south on Eugene Street, as laid down on the city plan, to its intersection with Delaware Avenue; then south on Delaware Avenue to effluent Shaft No. 11 at Lardner's Point pumping station. The nine intermediate working shafts were distributed along the line of work at locations about 1400 feet apart, making thus the average length of heading about 700 feet.

The depth of Shaft No. 1 at the Torresdale end of the conduit, measured from the finished head, is 127.39 feet, and of Shaft No. 11, at Lardner's Point, from same point of measurement, 117.05 feet. The length of tunnel between end shafts is 13,809.2 feet, and total length of water flow from the center of influent legs at Shaft No. 1 to the center of effluent legs at Shaft No. 11, about 13,968.5 feet. The diameter of Shaft No. 1, of the tunnel and the lower 68.1 feet of Shaft No. 11, is uniformly 10 feet 7 inches on the neat lines of brickwork. The upper 48.9 feet of Shaft No. 11 is 21 feet 1 inch in diameter.

The general depth of the center line of tunnel is about 100 feet below ground level.

The filtered water is drawn from the clear-water basin at Torresdale

to Shaft No. 1 through a concrete metal reënforced conduit of horseshoe section, equivalent in area to a circle 10 feet in diameter, 855 feet long from the outlet of the clear-water basin to the shaft. This conduit is connected with the shaft at elevation 186.50 T. D.* center line, through two cast-iron nozles bolted to the steel shell of the shaft, one 8 feet in diameter, and the other 7 feet in diameter, the direct connection to the conduit being made through the larger nozle. Each of the nozles is connected with the conduit, and the clear-water basin through lengths of riveted steel pipe, 21 feet long for the 8-foot nozle, and 14 feet long for the 7-foot nozle, the steel pipes being enveloped in concrete.

The effluent legs at Shaft No. 11 are respectively 14 feet and 7 feet in diameter, of riveted steel, each 28 feet in length, and, like the influent legs at Shaft No. 1, connected to the steel shell of the shaft with cast-iron nozles and rounded mouthpieces.

The elevations of the conduit and connections with reference to Torresdale datum are as follows:

Head of Shafts Nos. 1 and 11,	216.46
Invert of tunnel at Shaft No. 1,	89.07
Invert of tunnel at Shaft No. 11,	99.41
Center line of tunnel at midlength,	99.49
Invert of 8-foot connection at Shaft No. 1,	182.50
Invert of 7-foot connection at Shaft No. 1,	182.50
Invert of 14-foot connection at Shaft No. 11,	178.00
Invert of 7-foot connection at Shaft No. 11,	178.00
Floor clear-water basin, Torresdale,	192.00
High-water line, clear-water basin, Torresdale,	207.00
Invert of 10-foot conduit from clear-water basin to Shaft No. 1.	181.50

Down to the rock and for a short distance into it, until the shells were sealed, the permanent and working shafts were made of steel plate lined with brick. Below the rock the permanent shafts are brick backed with concrete. The working shafts were not thus lined, but the rock left in the condition found after blasting.

The bends at the bottom of the shaft are entirely of concrete, built to forms 10 feet 7 inches in diameter, on a radius of center line of 15 feet 9 inches, finished with a granolithic surface one inch thick. The tunnel is lined with hard burned brick backed with concrete.

The lining of invert is everywhere of two courses of brick, laid to templets on a cradle of concrete. The arch ring varies from 3 to 5 courses of brick, depending upon the nature of the material in the roof of the tunnel, above which concrete was packed up to the rock,

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* T. D., Torresdale datum, taken 200 feet below city datum, or mean high water in Delaware River.

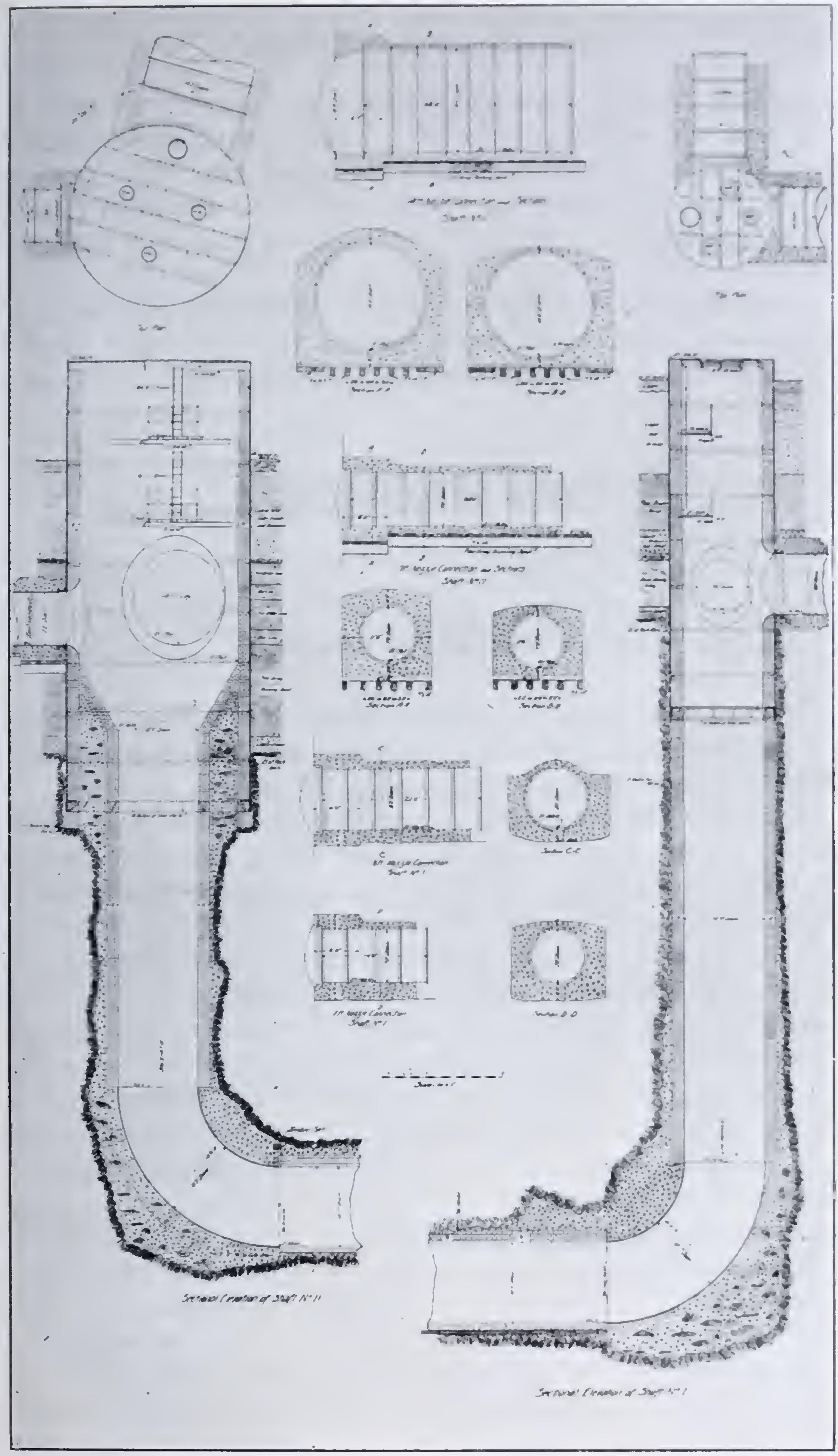

Plate I.—Typical Sections of Shafts No. 1 and No. 11.

and where, for lack of space above the arch ring, concrete could not be placed, the voids were filled with Portland cement grout pumped in under about 85 pounds' pressure per square inch. The grout was usually pumped through the weeper pipes set in the brick masonry to lead the water from back of the arch to the interior of the tunnel or shaft.

Considering the carrying capacity of 300,000,000 gallons a day, the velocity at different points between the clear-water basin at Torresdale and the pump-wells at Lardner's Point will be as follows:

	Feet per second.
From the clear-water basin at Torresdale to Shaft No. 1, ...	5.92
Combined 8-foot diameter and 7-foot diameter nozles at Shaft No. 1, ...	5.163
Shaft No. 1 and tunnel, ...	5.276
Shaft No. 11 at lower end, ...	5.276
Shaft No. 11 at upper end, ...	1.319
Aqueduct to pump-wells 2, 3, and 4, ...	3.015
Aqueduct to Lardner's Point pumping-station No. 1, ...	1.984

The total loss of head between the clear-water basin at Torresdale and pump-wells at Lardner's Point, when the conduit is delivering 300,000,000 gallons a day, is estimated at 9.25 feet.

To prevent the tunnel from becoming air bound it is graded upward 9 inches per 1000 feet from Shaft No. 1, Torresdale, to Shaft No. 11, Lardner's Point. Air which may be carried down Shaft No. 1 will either be carried into the tunnel or rise through the water in the shaft. Such air as may be carried into the tunnel will flow with the water and be vented at Shaft No. 11, the upward inclination of the tunnel from the influent to the effluent shaft preventing the accumulation of air, which might be a cause of interference with the operation of a horizontal tunnel. Should there ever be any indications of air sticking, as it were, in the conduit, it is believed that it can readily be removed by increasing the speed of the pumping machinery at Lardner's Point, lowering the level of water temporarily in the pump-wells, and creating an increased velocity of flow through the conduit until the air is removed. The conditions under which the water is conducted to the influent shaft, and the upward gradient of the tunnel from the influent to the effluent shafts, are thought to be effectual safeguards against the introduction of any considerable quantity of air into the conduit, or of any reduction of its capacity by the accumulation of air at any point along the roof.

Character of Materials on the Line of Work.

The only deep-rock operations from which information could be obtained upon the probable character of the material to be encountered in driving the shafts and headings for the northerly end of the conduit are found near the county prison, north of Pennypack Creek. Here the rock excavated in the deep quarry is very hard, with few seams or fissures, and a small amount of water, and the typical sections showing excavation for the conduit in hard rock were partially based on this information.

The experience with the conduit confirmed the diamond drill borings which showed that the character of the rock in the quarry is not maintained for the whole length of the work, and that a great change in the hardness and stability of material takes place in going from the north to the south end. The treacherous material, however, is not continuous, but occurs in reaches of the work, sometimes being abreast of and sometimes crossing the line of the tunnel diagonally.

The diamond drill borings which preceded the preparation of the detail plan indicated the varying character of the rock, but the rapidity with which some of the material would deteriorate upon contact with the air in the tunnel was not fully suspected in advance.

Operations on the conduit were conducted from nine working and two permanent (end) shafts. All shafts were lined to the solid rock. The working, as well as the permanent, shafts were constructed with steel shells sunk into hard rock and sealed, the interior being lined with an 18-inch ring of hard burned stretcher brick laid in cement mortar in the permanent shafts, and a 9-inch ring in the working shafts. The sinking and lining of the steel shells for the end shafts was much more carefully executed than it was for the working shafts, because the latter, upon completion of the work, were closed with brick arches continuous with the arch of the tunnel, above which were constructed in each shaft two relieving arches to take a part of the weight of the backfill of the shaft off the arch of the conduit. From the arch of the conduit to ground level the working shafts were solidly backfilled with selected materials.

About 91 per cent. of the entire tunnel excavation was in hornblendic and biotite gneiss rock, which required no timber to support the roof. In the north end the rock was very good, but the flow of water, as will be noticed later, was large enough to render it a matter

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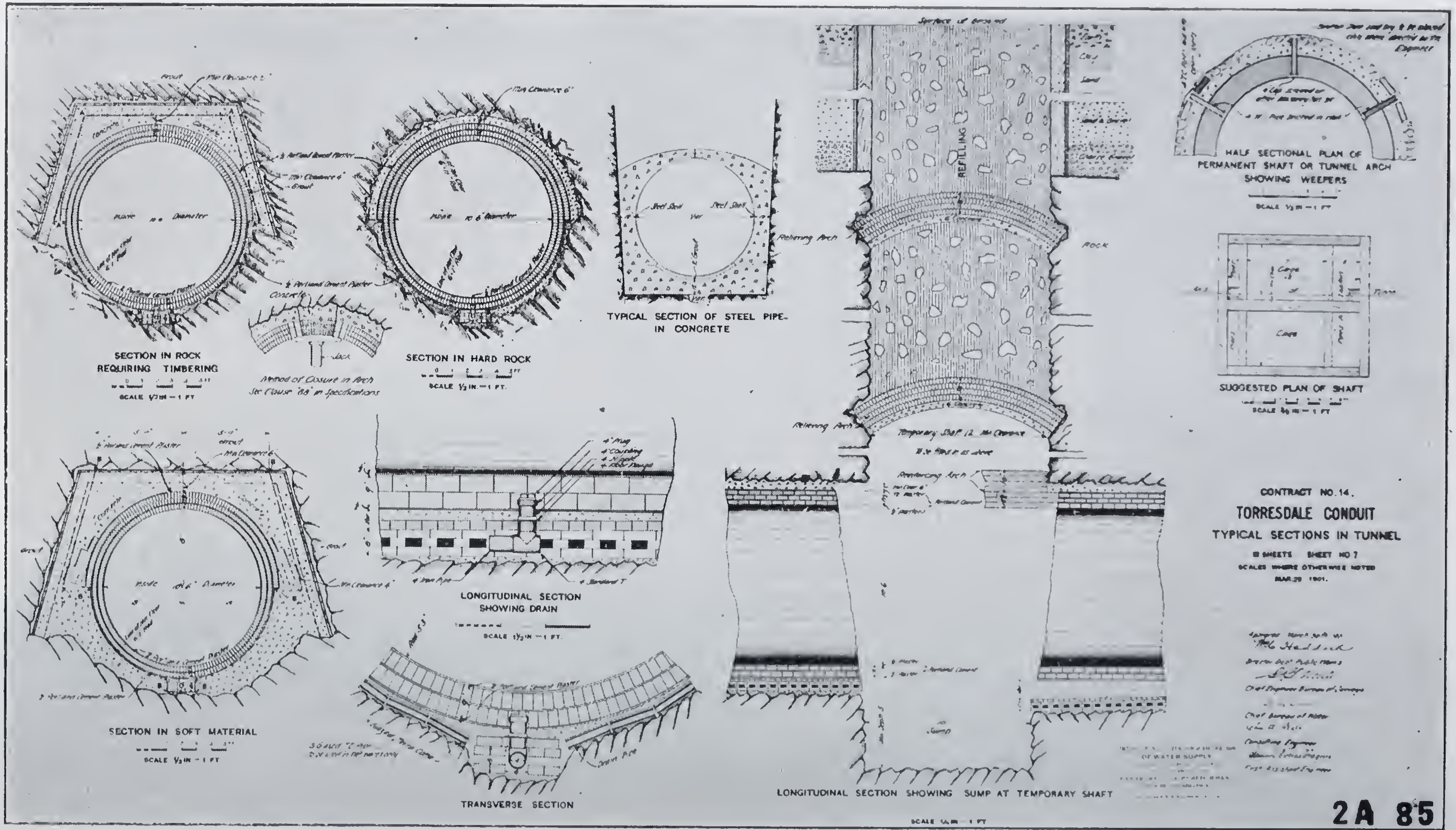


Plate II.—Typical Sections in Tunnel.

of concern to the contractor and interfered with the lining of the tunnel. Between Shafts Nos. 4 and 7 the rock was of excellent quality and the flow of water not enough to hinder the work.

Between Shafts Nos. 8 and 9, and in the north heading of Shaft No. 8, the micaceous rock was very rotten and treacherous, and required heavy and close timbering to prevent dangerous falls. In all such localities the thickness of the arch was increased to four or five rings of brickwork.

Excepting where falls in the roof occurred, the rough diameter of the excavation, heading and bench, is about 14 feet.

For several hundred feet in the north heading of Shaft No. 9, under the Disston Saw Works, the collar beams and posts supporting the roof abut against each other to prevent dangerous falls and possible injury to valuable surface structures. The placing of this timber not only delayed the progress of the excavation, but naturally occasioned great loss of time in its removal in part, and in placing the brick arch and the concrete packing above and around it.

In carrying forward the arch, for nearly 60 per cent. of the total length enough water was encountered dripping from the rock to make it almost impossible to insure proper setting of the mortar joints excepting the water was wholly excluded from the back of the brickwork, and in order to prevent this, wherever wet roof was met, tar paper in two layers from springing line to springing line of the arch was used to exclude the water until the mortar had set. It was not thought that the tar paper would be a permanent protection in this respect, but experience demonstrated that it could be relied upon to exclude the water for many days, during which time the mortar in the brickwork had sufficient time to harden.

In strengthening Shaft No. 7 as originally sunk and lined, while the contractor insisted that it was perfectly secure for his work, it was not thought that it was entirely safe either for the contractor's men or for the employees of the city, and in order to guard against any risk from inflow of water from the Delaware River, which, aside from the possible accidents to men employed in the shaft or in the headings driven, would have occasioned a very serious delay in recovering the shaft or in driving a new one, it was decided to reënforce with a ring of concrete from 12 to 18 inches thick, a portion of the shaft beginning 11 feet above the shoe of the steel shell, and continuing down 38 feet 6 inches into the excavated rock.

In the original plans for the work it was thought that the bends at the ends of Shafts Nos. 1 and 11 could be turned of brick, but study of the matter during progress of lining the tunnel led to the belief that these bends would be smoother, more uniform in section, and more stable if constructed of concrete than if the attempt was made to line them with brick. Forms were then built, bolted, and doweled together, carefully tested for dimensions at the surface of the ground, then taken apart, and set up in their true positions at the bottom of the shafts, around which was placed concrete entirely filling the spaces between the forms and the ragged rock around the excavation.

Air Compressors, etc.

Compressed air for the different sections of the work was furnished as follows:

Section 1: Shafts Nos. 1, 2, 3, and 4, by a Rand single stage compressor, with 24-inch air cylinder, 24-inch steam cylinder, 30-inch stroke, running at 83 revolutions a minute, located at Shaft No. 3 on the House of Correction grounds.

Section 2: Shafts Nos. 5 and 6, by two Ingersoll-Sergeant single stage compressors, with 22¼-inch air cylinders, 22-inch steam cylinders, 24-inch stroke, running at 94 revolutions a minute, located at the intersection of Eugene and Bleigh Streets.

Section 3: Shafts Nos. 7 and 8, by one Sullivan compound, or two stage compressors, with 14-inch and 22-inch air cylinders, 14-inch and 22-inch steam cylinders, all 24-inch stroke, running at 110 revolutions a minute. Located in the Pennsylvania Railroad yard at the foot of Disston Street, Tacony.

Section 4: Shafts Nos. 9, 10, and 11, by one Rand duplex compressor, with 20-inch air cylinder, 20-inch steam cylinder, 30-inch stroke, running 87 revolutions a minute; and one Ingersoll-Sergeant single stage compressor, with 12-inch air cylinder, 12¼-inch steam cylinder, and 14-inch stroke, running 155 revolutions a minute. Located at the intersection of Delaware Avenue and Levick Street.

The free air capacity provided for the different sections was as follows:

Section 1,	2670 cubic feet a minute.
" 2,	960 " " " "
" 3,	1160 " " " "
" 4,	2185 " " " "

Steam was supplied to the machines from locomotive and return

Plate III.—Cast Iron Shoe and Section of Steel Shell in Temporary Shafts.

Plate IV.—Head of Steel Shell, Shaft No. 7.

tubular boilers working at pressures ranging from 90 to 100 pounds by gage, and compressed air was used at from 70 to 80 pounds pressure by gage.

Head houses were built over each shaft excepting Shaft No. 11, where the elevation of muck and the lowering of men and materials was performed by a swinging boom derrick and dumping buckets. All head houses were provided with cages fitted with safety catches, upon which narrow-gage dump-cars were run for raising muck and lowering materials.

All rock drills and some of the pumps were operated by compressed air, the exhaust from which served to ventilate the headings and shafts.

Meeting of Headings.

In the following table are given the dates of meeting of headings, errors of line, errors of grade, and horizontal distance between shafts from which the operations were conducted.

Plumb-bobs and a Buff and Berger plunging transit both were used to project the line of the work from the surface of the ground to the bottom of the shaft. The large error of line at the meeting of the headings between Shafts Nos. 5 and 6 is due to the use on this section of the transit only in projecting the surface line down Shaft No. 5.

The error of line in the meeting of Shafts Nos. 3 and 4 was due to the same cause, Shaft No. 3 being too much out of plumb to admit of using the plumb-bobs.

Between Shafts.	Date.	Time.	Error in Line, Inches.	Error in Grade, Feet.	Distance Between Shafts, Feet.
Nos. 1–2	July 21, 1903	6.00 P. M.	5–$\frac{1}{4}$	0.007	1351
2–3	Apr. 12, "	7.00 A. M.	$\frac{5}{8}$	0.0312	1330
3–4	Feb. 7, "	5.30 P. M.	4	0.0208	1244
4–5	Apr. 27, "	7.00 P. M.	$\frac{1}{2}$	0.004	1640
5–6	Nov. 9, 1902	4.00 A. M.	7	0.0104	1353
6–7	May 23, 1903	3.00 A. M.	1–$\frac{1}{2}$	0.020	1562
7–8	May 13, "	6.00 P. M.	$\frac{1}{8}$	0.013	1635
8–9	June 6, "	12.00 M.	$\frac{3}{4}$	0.014	1580
9–10	Oct. 11, 1902	2.15 P. M.	$\frac{1}{4}$	0.0104	1110
10–11	Dec. 13, "	2.00 P. M.	1–$\frac{1}{4}$	0.0312	1003

History of the Contract.

The history of the contract is shown in the following table, including the assumed date of completion:

Date of letting,	May 28, 1901
Date of award,	August 28, 1901.
Date of contract,	October 4, 1901.
Date of revision of paragraphs 24 and 30 of the specification,	October 21, 1901.
Time limit for completion of work,	Nine (9) months.
Notice to begin work,	January 9, 1902.
Expiration of contract time,	October 9, 1902.
Date of completion,	April 23, 1904.
Default in time of completion,	424 working days.

There was at no time any indication of lack of energy on the part of the contractor to forward the work to the earliest possible completion. From its inception, about December 1, 1901, to April 23, 1904, at no time was the work even temporarily abandoned, although certain of the shafts, like Shaft No. 4 and Shaft No. 7, were, for reasons hereafter to be explained, abandoned for short lengths of time.

The first cause of delay was due to the decision of the city to deepen all the shafts by 10 feet, which conclusion was reached March 25, 1902, after Shaft No. 9 had been driven to the line of the tunnel. The terms of the contract provided that the first shaft (No. 9) which seemed to show from the diamond drill borings the poorest material in the rock should be driven in advance of the other shafts to the line of the tunnel, in order to determine whether the center line, as shown by the original plans, could be safely adopted for the prosecution of the work. Upon sinking this shaft to the elevation originally shown the material was found to be of such treacherous character that it was determined to lower the center line of the tunnel everywhere by 10 feet. Although several of the other shafts were in progress simultaneously with Shaft No. 9, they were not advanced as rapidly as this shaft, for the reason given.

In the construction of Shaft No. 7 in Eugene Street, between Cottman and Princeton Streets, and about opposite St. Vincent's Orphan Asylum, when the steel shell reached the rock and the work of driving into the rock was begun, it was regarded as unsafe for use, and work was temporarily suspended upon orders of the city until such time as the shaft might be made safe for the use of the engineers and inspectors, as well as the men in the employ of the contractor. Nearly

PLATE V.—SINKING STEEL SHELL, SHAFT NO. 9.

PLATE VI.—DIAPHRAGM FOR AIR LOCK, SHAFT NO. 2.

one month's time was lost between the date when the work was suspended and the operation again resumed.

In carrying forward the north heading from Shaft No. 9 a soft seam, consisting apparently of a mixture of plastic clay and rotten, micaceous rock, was encountered, requiring very careful and constant timbering of the work as the heading advanced. From November 6 to December 26, 1902, the rate of progress was less than 6 inches a day; from January 1 to February 5, 1903, the rate of progress represented less than 12 inches a day; the normal rate of progress throughout the work was slightly over 2 feet a day.

On February 5, 1902, owing to an accident, Shaft No. 4 was so seriously damaged that, notwithstanding vigorous efforts were made to reclaim it, it was finally abandoned on March 17, 1902, at a depth of about 50 feet below ground level. The second shaft was then located about 100 feet south of original Shaft No. 4, and driven down to the line of the tunnel without any further trouble at this station.

Owing to the inflow of water an attempt was made to use an air lock on Shaft No. 2, but after trial of about six weeks this was removed and progress continued to the end of the work in the open shaft and headings.

During the coal strike in 1902 serious difficulty was encountered in securing enough coal to keep the machinery running at all the shafts, and especially between Shafts Nos. 1 and 8 there were times when the supply of fuel was so low as to prevent the working of the usual double shift of men. In due time this trouble was remedied through the kindly aid of the officials of the Pennsylvania Railroad.

Considering the very large amount of brick required for lining the permanent shafts and tunnel (over 9,700,000) considerable difficulty was experienced in getting brick of a satisfactory quality. Several cargos of brick were offered for use and rejected entirely by reason of the very large percentage found unsuitable upon inspection, and the contractor was, therefore, directed to procure bricks from manufacturers whose general run of material met the requirements of "sound, straight, hard-burned brick, uniform in size and structure, and with true even faces." In fact, it was not possible to get the large quantity of brick required in the lining of the tunnel and permanent shafts from one manufacturer, and to meet the conditions, excepting as to size, and avoid delay, two sizes of brick were used. The first brickwork was placed in Section 4, January 3, 1903.

Plastering Brickwork.

Concerning the one-half inch coat of Portland cement plaster on the face of the brickwork in the conduit, which was omitted because it was found impossible to make it continuous from end to end of the conduit by reason of the dampness of the brickwork in the arch, there is some doubt in my mind whether any decided advantage in the smoothness of the interior of the conduit for a great length of time would be accomplished by the plaster coating. The experience of Mr. James M. Gale, engineer in charge of the waterworks of Glasgow, who built the second aqueduct which brings the water from Loch Katrine to the Mugdock reservoir, has raised a doubt of the advisability of plastering a conduit intended to carry a reasonably soft water, such as is the water from the Delaware River. The solvent action of soft water upon the uncombined lime in Portland cement mortar is well known, and it is possible that in due time the Delaware River water would have pitted and roughened the surface of the plaster lining so as to render it less smooth than well-laid brickwork with struck and trimmed joints. In the construction of the invert of the tunnel and in the construction of the rings in the shafts all joints were struck. This, of course, was not possible in the construction of the brickwork of the arch, but upon removing the centers and after the mortar had set, all excess mortar in the soffit joints was carefully trimmed away from end to end of the conduit. While it is true that, at joints in the lining of the conduit, there is some noticeable irregularity or lack of smoothness in the brickwork, this represents a very small portion of the 14,000 feet of conduit, and by far the larger percentage of the shafts and tunnel consists of brickwork as smooth as any that I have ever seen laid in sewer work where the operations were conducted in open cut, and under much more favorable conditions for neat bricklaying than were found in the conduit.

When it became evident that the plastering could not be made to stick to the brickwork of the arch, about 21 per cent. of the total length of arch had been placed, and orders were then issued to the contractor and the engineers and inspectors in charge of the lining to exercise especial care in building the arch true to line and radius, in view of the probability that the plastering of the brickwork could not be accomplished and that the face of the brick lining would be, upon completion, the wetted perimeter. At least 79 per cent. of the

Plate VII.—Method of Drilling in Hard Rock.

Plate VIII.—Excavation in Hard Rock, South Heading, Shaft No. 1.

soffit of the arch is as true and smooth as the lining of the invert which was laid to templets with struck joints.

The only real objection to the omission of the cement plastering was the possible reduction of carrying capacity, and if experience should show this to be the result, it would then assume a serious phase. But directly it was demonstrated that the plastering could not be successfully and continuously applied to the arch, extra precautions were taken in laying the brickwork, and upon drawing the centering all excess mortar in the joints was chipped away flush with the face of the arch.

Investigations of the value of "n" in the Kutter formula for flow of water in closed channels, of plastered and unplastered brickwork, seemed to show that "n" = .013 could safely be applied to the unplastered brickwork of the conduit, and if this conclusion is well founded, it should have the full capacity intended, with unplastered arch 10 feet 7 inches in diameter. As a rule, the invert was a very smooth piece of brickwork, and it is not thought that plastering would have materially improved this in flowing function.

Portland Cement and Concrete.

Only Portland cement was used in all parts of the work as follows:

	24,162	barrels of Star Bonneville.
	9,650	" " Lehigh.
	675	" " Saturn.
	450	" " Giant.
Total, ...	34,937	

Concrete was mixed in the following proportions:

For the cradle of invert and packing of arch:

1	part	cement.
3	parts	sand.
5	"	broken stone ballast.

For the bends at Shafts Nos. 1 and 11:

1	part	cement.
1½	"	sand.
1½	"	limestone screenings.
5	parts	broken stone ballast.

Face work of bends:

1	part	cement.
1	"	sand.
1	"	limestone screenings

Concrete Cubes.

During the progress of the work 418 concrete cubes were made as samples of the material used in the construction of the cradle and of the arch, and these were broken after sixty, ninety, one hundred and twenty days, and six months; and the very best concrete, as shown by the compression tests, used anywhere in the work of the improvement, extension, and filtration of the water supply, was used by the contractor for Contract No. 14, some of the cubes exceeding 5000 pounds per square inch in the crushing test.

Cost of the Work.

Contract price,		$1,274,000.00
Extras authorized by city,	$68,505.33	
Deduct scrap steel sold and work not performed,	546.60	67,958.73
Total cost,		$1,341,958.73
From which deduct plastering not placed,		20,735.54
Difference,		$1,321,223.19

The probable cost of the work to the contractor from the record of labor and materials furnished was $1,306,186.62, or $93.10 per linear foot.

The quantities of materials as per original estimate, prior to making of contract, and as actually performed, are shown in the following table:

1. Items.	2. Original Quantities From Plans.	3. Quantities Actually Performed.	4. Increase Over Original Estimate	5. Additional Quantities Not Included in Cols. 3, 4, Ordered as Extras
Excavation—				
Tunnel, cubic yards,	83,670	89,366.90	5,696.9	....
Shaft, " "	5,632	7,425.00	1,793.0	21.0
Concrete, " "	22,381	24,058.00	1,677.0	3,278.8
Brick masonry, cu. yds.	18,802	18,360.45	....	1,145.7
Plastering, linear feet,	14,058	....	....	....
Cast-iron, lbs.,	117,640	128,578.00	10,938	....
Steel, "	346,374	353,205.00	6,831	....
Clay for puddle, cu. yds.	....	....	....	94.5
Tar paper, single thickness, square feet,	....	....	....	619,000

The additional shaft excavation was authorized under the provision of the contract which permitted a lowering of the center

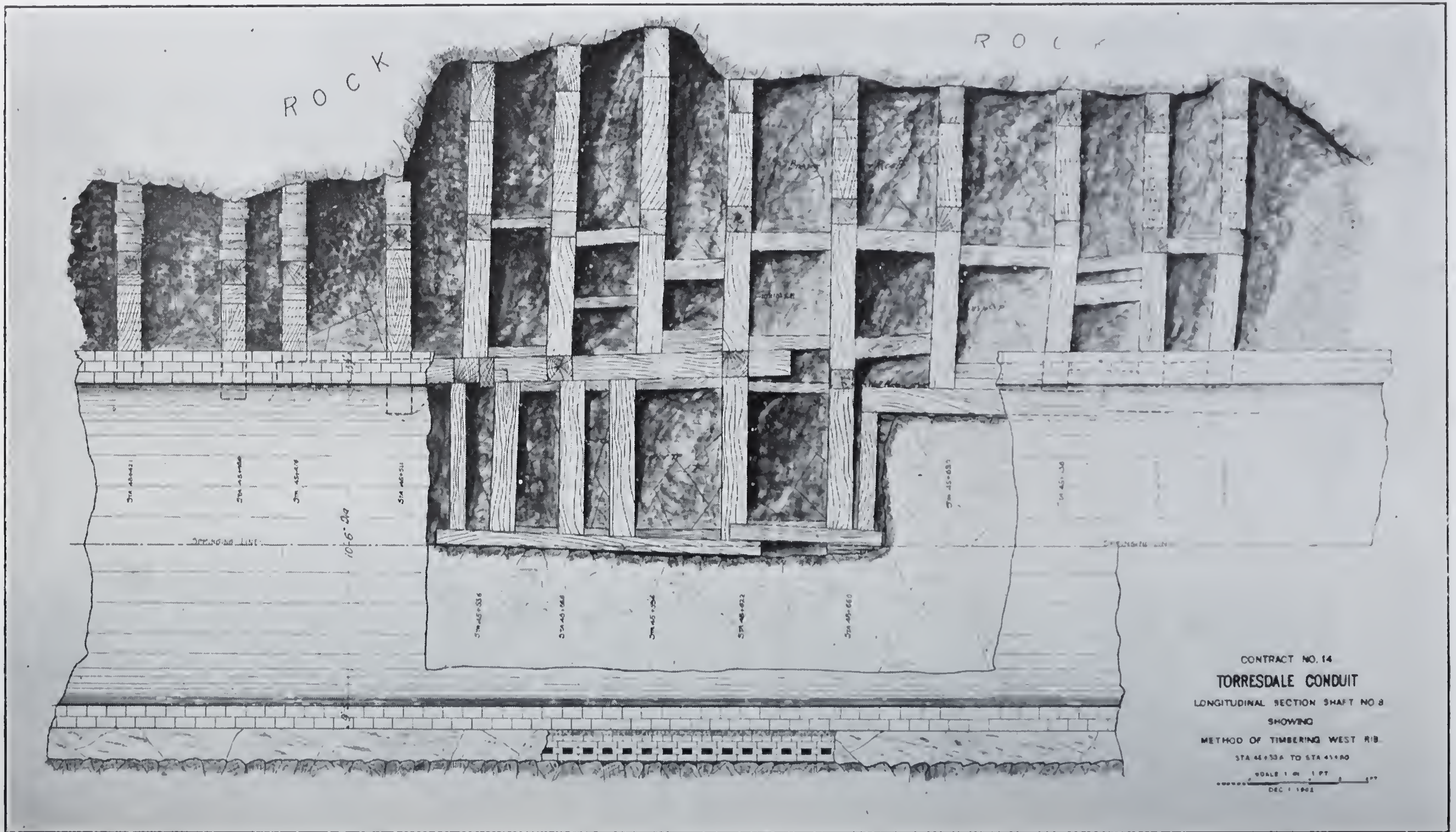


Plate IX.—Timbering in Soft Rock, North Heading, Shaft No. 8.

line of tunnel if found advisable so to do upon sinking Shaft No. 9 to the line of tunnel.

The clay puddle was used over the arch of the closures for the working shafts to render these watertight, while the mortar in the brick was setting. Two thicknesses of three-ply tar paper, not included in the original plans, was used over the brick arch where this was laid under wet roof.

Addition to Quantities.

In addition to the above statement of quantities of work performed, there was used, but not incorporated, as such in the estimates, the following materials:

34,937 barrels of cement.
9,703,700 bricks.
12,688 cubic yards sand.
16,725 " " ballast.
11,184 linear feet of 6-inch terra-cotta pipe.
138,814 feet B. M. timber.

In apportioning the lump sum bid for the several items entering into the construction of the work, for the purpose of current estimates, the following unit prices were used:

Excavation in tunnel,	$7.90 per cu. yd.
Excavation in shafts,	19.00 "
Concrete,	9.00 "
Brickwork,	13.00 "
Plastering interior of brick lining,	1.475 per linear foot.
Castings,	0.07 per lb.
Steel work,	0.09 "

Cost of Tunnel Compared to Pipe Line.

Upon the assumption that the cost of the conduit is based on the limit of contract, viz., $1,350,000, the cost per linear foot becomes:

$$\frac{1{,}350{,}000}{14{,}030} = \$96.22.$$

Relating this to the cost of 12 equivalent lines of 48-inch cast-iron pipe aggregating 38.8 miles, viz., $38.8 \times 5{,}280 \times \$16.00 = \$3{,}277{,}824$.

Or, reduced to the length of the tunnel, the cost per linear foot becomes:

$$\frac{3{,}277{,}824}{14{,}030} = \$233.62.$$

Fatal Accidents.

During the construction of the conduit 14 lives were lost, as follows:

Shaft No. 1, November 20, 1902: One man killed by the fall of a fragment of rock from the side of the shaft.

Shaft No. 2, June 2, 1902: Foreman killed while riding down the shaft on a pump which was being lowered to position at the bottom of the shaft, by a piece of pipe which became disconnected and fell.

Shaft No. 3, August 14, 1902: The pump man at foot of shaft killed by dropping of a drill from the cage in the shaft.

January 10, 1903: One man fatally burned in a shack fired by an explosion of dynamite stored in the magazine.

Shaft No. 4, July 31, 1902: One man killed by being struck by the boom of derrick and knocked into shaft.

Shaft No. 7, May 20, and May 21, 1902: Two men fatally overcome by powder fumes in the heading.

Shaft No. 9, April 30, 1902: Three men killed at one time by the tipping of a bucket in which they were being drawn up out of the shaft. The hoisting engine developed some trouble, and just as the boom of the derrick was being swung clear of the shaft, the hoisting rope slipped and bucket struck on the upper edge of the steel shell and dumped the men into the shaft.

Shaft No. 10, April 5, 1902: One man was killed by being crushed between the side of the shaft and the discharge pipe of a pump which was being lowered.

Shaft No. 10, December 2, 1902: One man killed by being hit in the head by a fragment of rock from a blast fired in the south heading, 400 feet distant.

Shaft No. 10, December 4, 1902: One man killed by fall of rock from the roof in the south heading.

Pennypack Creek: Between Shafts Nos. 1 and 2 man drowned by leaping from the transfer boat, which he supposed was sinking.

Estimated Carrying Capacity.

Data upon the actual flowing capacity of large brick-lined conduits under pressure are very meager, but with the loss of head between Shaft No. 1, at Torresdale, and Shaft No. 11, at Lardner's Point, of 8.6 feet, it is assumed that the conduit will have a carrying capacity of 300,000,000 gallons a day of twenty-four hours.

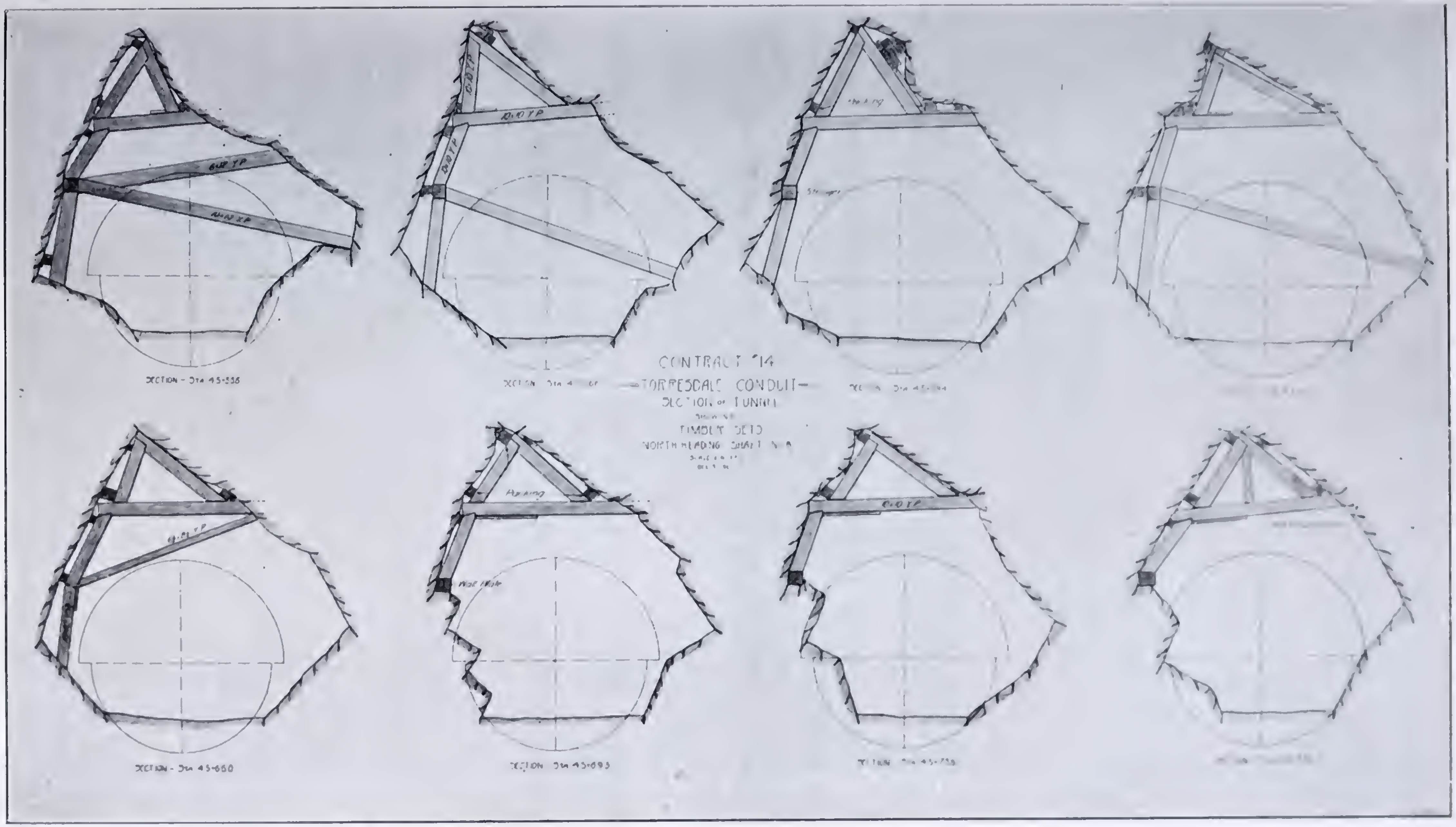


PLATE X.—TIMBER SETS IN NORTH HEADING, SHAFT NO. 8.

By Kutter's formula, with "n" taken at 0.013, the capacity for the given loss of head will be:

$$V = 136, \sqrt{2.645 \times .000616} = 5.484 \text{ feet.}$$
$$Q = 5.484 \times 87.97 = 482.427 \text{ cubic feet.}$$
$$G = \frac{482.427}{1.5472} = 311.8 \text{ million gallons a day.}$$

By Lampe's formula:

$$V = 167.89 \times r^{.694} \times s^{.555} = 5.455 \text{ feet.}$$
$$Q = 5.455 \times 87.97 = 478.987 \text{ cubic feet.}$$
$$G = \frac{478.987}{1.5472} = 309.6 \text{ million gallons a day.}$$

The capacity, of course, can be increased by lowering the level in the pump-wells at Lardner's Point, and increasing the loss of head in the conduit.

The cubic contents of the conduit, taken to the normal level of ground water, 197.00 T. D., is 9,253,932 gallons, and the time required for water to flow from Shaft No. 1 to Shaft No. 11, when the conduit is delivering 300,000,000 gallons a day, will be about forty-four minutes.

Comparison of Conduit and Equivalent System of 48-inch Gravity Cast-iron Pipes.

In order to balance the carrying capacity of the Torresdale conduit with a system of cast-iron gravity pipe with the same loss of head, it will require 12 lines of 48-inch cast-iron pipe of an average length of 17,100 feet for each line, or a total length of 38.8 miles.

Experience has shown that a leakage of 8,630 gallons per mile per day of twenty-four hours in a line of 48-inch cast-iron pipe, operating under a pressure of 50 pounds per square inch, is allowable under all ordinary conditions. The head required for a flow of 25,000,000 gallons per day through each of the 12 lines of 48-inch pipe mentioned is 10.3 feet; and prorating the leakage on the square roots of the heads, the allowable leakage for 38.8 miles of 48-inch cast-iron pipe having the same capacity as the Torresdale conduit, amounts to 100,000 gallons a day of twenty-four hours.

The cost of the cast-iron gravity conduit would have been, at the prices prevailing when the conduit was let by contract, about $3,-278,000, or $1,928,000 more than the cost of the structure as built.

The interest charges alone on the difference of cost at 3½ per cent. would have been $67,474, while the annual charge due to the probable loss of 200,000 gallons of filtered water a day at $5 for filtration and low-service pumpage, and $3.84 for interest charges on the Torresdale works, will amount to $6,453.20.

But it has been shown that an allowance of 100,000 gallons a day for the leakage of the cast-iron pipes is reasonable, and hence of the annual value of water lost, one-half only should be charged against the conduit, or $3,226.60; about one-twentieth of the interest charges on the increased cost of cast-iron gravity pipe lines.

Examination of the Conduit.

After closing the last two working shafts, Nos. 2 and 7, early in April, 1904, and removing the pumping machinery from Shaft No. 1, daily observations were taken from April 8 to 18 on the rise of water in the tunnel and end-shafts.

After plotting the elevations of water-level and corresponding leakage it was found that the leakage was greater than was anticipated at the time of removal of the pumps, and more than could be readily accounted for, provided the sump at Shaft No. 1 and all open weepers had been properly closed.

The contractor's attention was promptly called to the apparent excessive leakage, and after full consideration of the matter it was finally decided to pump out the conduit, make an examination of the interior, and correct any defects or oversights of the contractor's work which such examination might reveal.

The Results of Examination.

After considerable delay in making the necessary arrangements for head house, boilers, and pump to empty the conduit, the work of pumping out was started August 13, 1904, using for this purpose at first a No. 8 DeLaval steam turbine, having a rated capacity of 1200 gallons a minute under 125 feet head, and later a No. 9 and a No. 11 Cameron shaft sinking pumps. The No. 9 Cameron pump had a capacity of 300 gallons a minute, and the No. 11 Cameron, a capacity of 450 gallons a minute.

The pumps were hung on wire cables from hand winches and chain blocks in such manner that they could be lowered as the water-level

Plate XI.—Timbering, Shaft No. 8, North Heading.

Plate XII.—Timbering, Shaft No. 9, South Heading.

in the shaft was reduced; and as each pump was lowered by stages in this manner, the three lines of pipe reaching from ground level to the pumps was increased by adding sections uniformly 10 feet in length.

The discharge of the pumps was carried into a tight wooden sluiceway and run into a weir-box having a width of 5 feet, a depth of 1 foot 9 inches below the weir crest, and a length of 14 feet, and provided with the usual screens to smooth the water before it approached the weir, and with a weir having a notch 21 inches wide by 9 inches deep. The weir was made of brass plate, with sharp edge, set truly plumb, and at right angles to the axis of the weir-box, and with the crest level from end to end. The heads on the weir were read by means of an ordinary hook gage with vernier reading to one-thousandth of a foot, set in a stilling-box outside the weir-box, and connected with the latter by means of a perforated iron pipe laid across the bottom, about three feet up-stream from the weir.

All conditions for accurate measurement of the water pumped from the conduit were carefully observed, the point of the hook gage being referred to the crest of the weir from day to day by means of a "Y" level and leveling rod.

The same outfit, of course, served not only to measure the rate at which water was being removed from the conduit before it was emptied, but after it was emptied, to gage the leakage, all of which, of course, was removed from Shaft No. 1 and discharged over the weir.

Observations of the head on the weir; of the level of the water in Shaft No. 1, and of the general conduct of the work, were made hourly, night and day, throughout the operations, from the time the pump was started on August 13, 1904, until December 17, when the pumps and all other material were removed from Shaft No. 1, and preparations made to close the shaft head, and after this until January 12, at which time the ground water having reached elevation 193.00 T. D., was rising at such a slow rate as to render further observations unnecessary.

The depth and diameter of the shaft rendered all operations for pumping out and repairing the conduit very difficult. After the two Cameron shaft sinking pumps and the DeLaval steam turbine, with their steam exhaust and discharge pipes, had been hung, the remaining space for lowering men and materials was too small for a cage or even a bucket, and only about large enough to accommodate a boatswain's chair suspended from the hook of the derrick. I cannot compliment too highly the riggers and engineers in charge of the derrick for their

careful work for the period of one hundred and thirty-two days of active operations, during which time no serious accident to men or machinery occurred.

October 20, 1904, the water was lowered in the conduit until the depth over the invert at Shaft No. 1 was such as to permit of an examination being made from end to end, at which time it was discovered that the sumps at Shaft No. 1 and Shaft No. 2 had not been closed. In addition to the open sumps, considerable water was coming into the conduit through a number of large open joints in the brick-work, and from several particularly wet spots in the arch between Shafts No. 8 and No. 11, but by far the largest proportion of leakage was from the two open sumps, as the gagings later given will show.

Closing Sumps.

The sump at Shaft No. 1 was closed in the following manner: An opening about 8 feet long by 5 feet wide was cut through the brick invert and concrete cradle for a depth from the center of invert of 24 inches. The center of the sump thus formed was further excavated by blasting the rock for a depth of 14 or 15 inches to accommodate the suction of the No. 11 Cameron pump, which was arranged to pump the water away from this sump until it was finally closed. Over the bottom of the excavation coarse gravel and boulders were carefully spread by hand and leveled for a foundation for the casting or "sump closer." On the gravel was set, and lined and leveled, a flared cast-iron box, measuring 6 feet 6½ inches in length, by 3 feet 3½ inches in width over the lower flange, and 5 feet 10½ inches in length, by 2 feet 6½ inches in width over the upper flange, with an anchor flange at midheight having a mean of above dimensions.

The internal dimensions of the box were 5 feet 7¼ inches long at the bottom, and 5 feet long at the top, by 2 feet 4½ inches wide at the bottom, and 1 foot 8 inches wide at the top. Across the casting at midlength a bridge was cast.

The upper flange was planed and drilled for one-inch diameter studs, and the casting was closed by a cover divided at midlength with a sharp "V"-shaped groove for lead joint at the junction of the two plates.

The box was everywhere 1¼ inch thick, and the cover 1½ inch thick.

One section of the cover plate was bored, drilled, and tapped in

Plate XIII.—Form for Turning Concrete Bend, Shaft No. 11.

Plate XIV.—Lining of Tunnel Looking Towards Shaft No. 2.

the center for a 6-inch union flange and short 6-inch nipple with a flange on the top to accommodate the suction of the Cameron pump.

The casting was leveled on the gravel base; the water pumped down to and maintained at the level of the lower flange, and the box concreted in place, leaving, of course, the center open to serve as a sump until the opening was finally closed. After the concrete had set for two weeks, the cover plates were bolted down on white pine gaskets; the "V" opening between the plates caulked with lead, and the pump suction reduced in size and set in the 6-inch riser in one of the cover plates. The riser, upon removal of the pump, was closed with a 6-inch flange bolted down on a white pine gasket.

To bring the water freely from the sides of the sump to the center of the casting short lengths of old 4-inch boiler flues were set in place as the gravel was laid.

When the sump was closed, it was perfectly water-tight. All the work connected with the placing, concreting, and final closing of the casting was performed under the supervision of Mr. John E. Powell, superintendent in charge of repairs.

At the open sump at Shaft No. 2 a different plan was adopted. Here the original plan was to square the opening carefully to the smallest possible dimensions; fill the hole with coarse gravel; set above it, on the invert, a stout wooden form braced down and made watertight by caulking around the edges, and pump grout into the opening under 50 or 60 pounds' pressure through a 2-inch pipe set in the form. In cutting out the hole the workmen misunderstood orders and made the sump large enough to receive the form. This mistake or blunder caused at least two weeks' additional work, and largely increased the cost and difficulty of closing the sump.

Several expedients were adopted and failed of the purpose, and finally a No. 4 centrifugal pump of 400 gallons capacity a minute was set up near the sump. An alternating current motor was procured and set up on a temporary timber platform, and belted to the pump, and the current to operate the motor carried in from Shaft No. 1—a distance of 1400 feet. The suction of the pump was then set in the bottom of the sump, and the discharge set in a sluice-box which delivered the water north of a temporary sand-bag and clay dam placed north of the sump.

A similar dam was built south of the sump, and the water from south of Shaft No. 2 flumed across the opening under the shaft.

When the pump was put in service, delivering about 350 gallons a

minute, the sump and invert of the conduit were laid dry, and operations to close the sump permanently commenced.

In the center of the sump, on a coarse gravel foundation, as at Shaft No. 1, a short length of 12-inch steam pipe with a flange top and bottom was set, with the upper flange about 5 inches below the line of tunnel invert. In this nipple was set the suction pipe of the centrifugal pump, which was operated constantly day and night to keep the opening dry.

Railroad bars, cut about four feet long, were placed at right angles and diagonally across the opening above the lower flange of the 12-inch nipple, and securely anchored at the ends under the old concrete cradle of the conduit. Concrete was then rammed in the dry hole up to the level of the upper flange, around the nipple, and up to the line of the invert around the hole outside the nipple. The nipple, after the concrete had set for over a week, was closed with a blank flange bolted down on a white pine gasket, and the depression of four or five inches over the cap finished to the line of the invert with a fine cement mortar. This sump when closed was perfectly watertight.

When the sumps were closed, a portion of the water which previously issued from them forced its way through the concrete and brickwork between Shafts Nos. 1 and 3. The work at Shaft No. 2 was also conducted under the supervision of Mr. Powell.

In anchoring in place with concrete, the sump casting at Shaft No. 1, and the nipple at Shaft No. 2, due consideration was given to the pressures which would come upon them when closed, and the water forced to seek other, though less convenient, points of efflux.

The hydrostatic pressure of the water in the rock at the bottom of the conduit was roughly 43 pounds per square inch, and the upward pressure on the sump casting at Shaft No. 1, and on the nipple and railroad bars at Shaft No. 2, was estimated as over 40 tons in each instance.

The necessity of operating a power pump at Shaft No. 2, so far from the only open shaft at the north end of the conduit, imposed an unusual difficulty, and nothing in all probability could have satisfied the conditions so well as the electric current and motor employed.

Many open weepers and joints in the brickwork were found, and all these were carefully closed with poplar plugs and white pine wedges, and where considerable water flowed in spots from the roof or arch, holes were jumpered through the brickwork and concrete,

Plate XV.—Top Section of Steel Shell, Shaft No. 11.

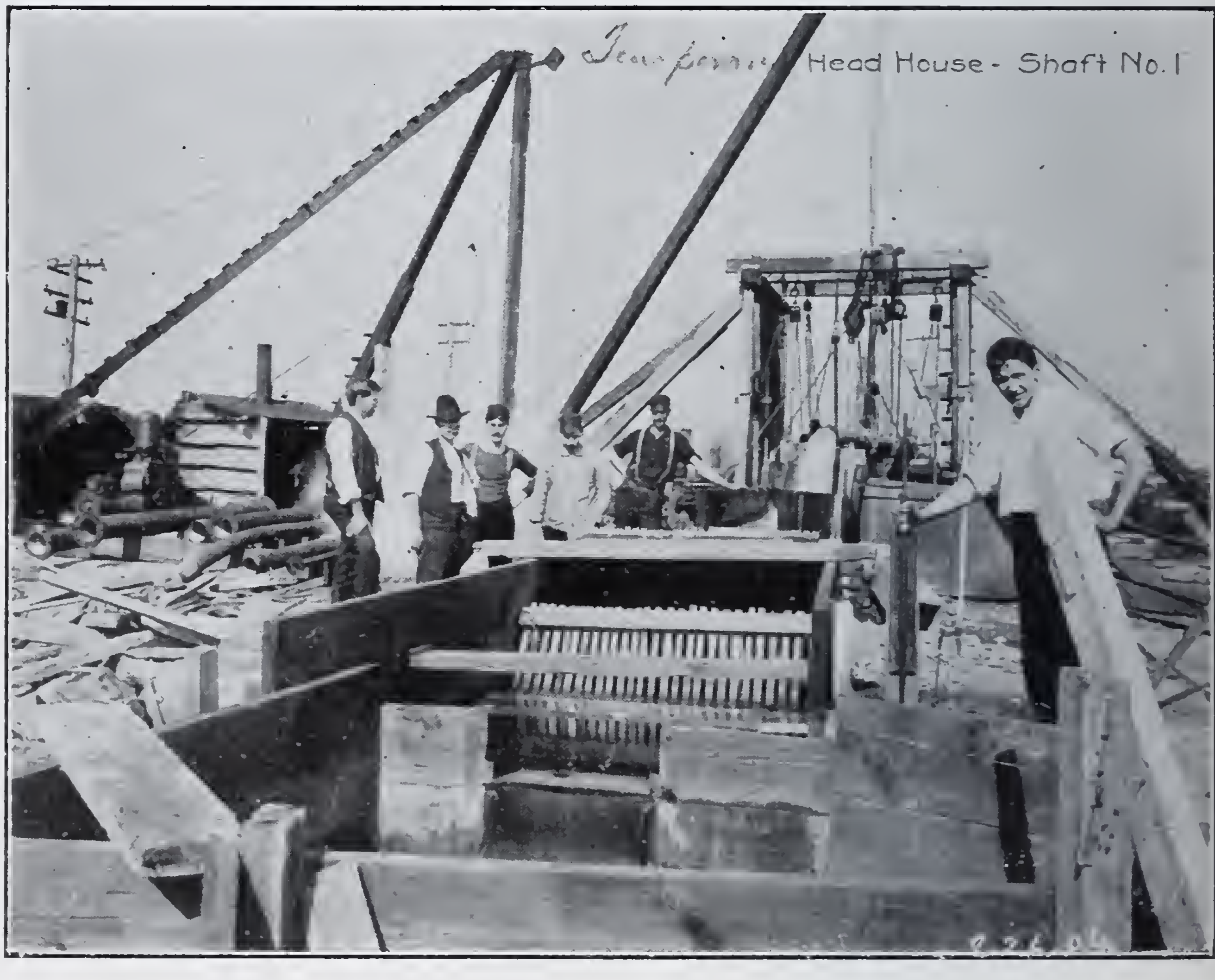


Plate XVI.—Temporary Head House, Shaft No. 1.

iron pipes driven in, and grout pumped over the arch under pressures up to 100 pounds per square inch.

Grout was used generally in the proportion of four parts of cement to one part of fine sand, although in some cases the sand was omitted.

Upon entering the conduit considerable dirt, débris timber, and loose brick from the construction work were found lying on the invert. Planks left in the tunnel had become water-logged and impregnated with iron from the rock water, and lay on the invert. All this material was removed, slush from the cement mortar used in laying the brick-work carefully washed out, and removed either at Shaft No. 1 or Shaft No. 11, whichever happened to be nearest.

In closing the shafts after the pumps, pipes and other hamper were removed, steel buckle plates one-quarter inch thick, bent to the intrados of the brick arches, were set on the lower flanges of the "I" beams spanning the shafts, and left in place after the brick arches were turned and covered with concrete. This was done to avoid the use of wooden centers, which could not conveniently be removed after the arches were turned.

It is probable that all the real work performed in closing the sumps and weepers, in plugging open joints in the brickwork, and in grouting over the arches, could have been performed by the contractor before he drew the pumps from Shaft No. 1, at a cost of $1,000, while the operations performed under unusual difficulties, of installing new pumping machinery, hoisting apparatus, steam and water pipes, electric currents, etc., including all labor of cleaning out the conduit, cost over $22,000, illustrating the old adage that "Haste makes waste," and the other old adage, that "What is not in a man's head is in his heels."

Measuring the Leakage.

Information on the leakage of structures like the Torresdale conduit is very meager; few such conduits have been built, and very little data recorded of the water lost or gained either during or after construction, and of the structure in service. The inverted siphon of the second Croton aqueduct under the Harlem River; the Washington aqueduct, and the Jersey City conduit are examples in point; ordinary railway tunnels are not comparable to the Torresdale conduit, because the former are nearly always cut through elevated ridges or knobs much above tide level, are usually self-draining, and not subject to the influence of the water-level in nearby streams at higher elevation

than the line of the work. Exceptions may be noted in railway tunnels which pass under rivers like the St. Clair Tunnel at Detroit, the tunnels under the Chicago River at Chicago, and under the Thames in London. The Wachuset aqueduct, which is a similar structure, I am advised by Mr. Frederick P. Stearns, chief engineer of the Metropolitan Water Board, Boston, was not tested for watertightness. No evidence of leakage is known to exist, but no data have been recorded to prove absolute watertightness of the structure. No data are to be found in the office of the city engineer of Chicago, showing either construction or service leakage of the lake tunnels. It is probable that these are practically watertight, because they are driven through a tough, impervious clay. In the construction of the Cleveland tunnel compressed air was used, and, aside from this, the material through which the tunnel is driven was a tough clay, practically impervious, and therefore not comparable with the tunnel driven through such material as was found in the line of the Torresdale conduit.

Gaging in Empty Conduit.

The gaging in the empty conduit was done with a 15-inch brass weir screwed to the face of a 2-inch plank, about 7 feet long, cut to the radius of the invert 5 feet 3½ inches. The weir plate was accurately constructed with a sharp edge uniformly 15 inches long, with a depth of notch of 6 inches. After this had been carefully set plumb at right angles to the axis of the conduit, with the crest of the weir level, and secured in position by bracing against the arch, and by the use of sand-bags placed on the down-stream side of the weir clear of the notch and overfall, the joint between the segment of the plank and the brickwork was made tight with clay, so that all water was required to pass through the notch of the weir. The gaging was done by measuring from a stiff arm attached to the top of the weir board and extending about two feet up-stream, carrying at its end a thin, vertical strip of wood with small wooden lug at the bottom. The lug was in each case carefully adjusted to the level of the crest of the weir by a straight edge and spirit-level, and fixed firmly in position. The depths on the weir were gaged by means of a thin steel rule set on the lug. The accuracy of adjustment of the lug was tested before and after readings were taken, and the depth on the weir was determined by taking the submerged length of the rule from the lug to the level of the water.

Plate XVII.—Foot of Shaft No. 1.

Plate XVIII.—Lining of Tunnel under Shaft No. 2.

Readings of the flow in the tunnel were taken at intervals of fifteen minutes, and until they showed no further increase in the head on the weir. After the régime of water flow was established in this manner, the weir was then moved to a new station. The heads noted on the weir at different points were converted into volumes of flow after the formula—

$$q = c. \tfrac{2}{3} \sqrt{2g}.\ b.\ H^{\frac{3}{2}}$$

In the following table are given the final gagings taken before the pumps were removed from Shaft No. 1. The notes from stations south of Shaft No. 2 were taken before all the operations for reduction of the leakage had been completed, but the gagings at Shaft No. 2, and at the top of Shaft No. 1, took into account all the water flowing at the respective stations, which included for Shaft No. 2 all leakage between that station and Shaft No. 11, and the gaging at Shaft No. 1 of course included all water coming from the conduit. It is thus probable that the leakage south of Shaft No. 2 was less than the table shows, and the leakage from Shaft No. 1 to Shaft No. 2 correspondingly more than 364 gallons a minute.

Station.	Length of Tunnel Embraced in Gaging, Linear Feet.	Flow for Station, Gallons.	Accumulated Flow at Station, Gallons.
At Shaft No. 11,	0	9	9
Between Shafts Nos. 9–10,	1557.81	84	93
" " 8–9,	1345.00	23	116
" " 7–8,	1607.50	81	197
" " 6–7,	1537.50	57	254
" " 5–6,	1557.00	92	346
" " 4–5,	1508.00	84	430
" " 3–4,	1442.00	44	474
" " 2–3,	1238.00	162	636
From midway between Shafts Nos. 2–3 to and including Shaft No. 1,	2016.00	202	838

Of the 838 gallons a minute for the whole conduit, 364, or over 40 per cent., occur between Shaft No. 1, and midway between Shafts Nos. 2 and 3, a distance of 2016 linear feet.

For a period of fifteen days,—June 1 to 15 inclusive, 1903,—at a time when the water from Shaft No. 1 and its connected headings was being pumped separately, *i. e.*, when the water from one section

of the work was not allowed to flow to and be pumped from another section, the average leakage was at—

	Gallons a Minute.
Shaft No. 1,	350
" 2,	336
" 3,	122
Total,	808

For a period of fifteen days—June 16–30 inclusive:

Shaft No. 1,	294
" 2,	416
" 3,	102
Total,	812

For a period of fifteen days—July 1–15 inclusive:

Shaft No. 1,	248.2
" 2,	362.8
" 3,	96.0
Total,	707.0

For a period of sixteen days—July 16–31 inclusive:

Shaft No. 1,	305
" 2,	328
" 3,	95
Total,	728

For a period of fifteen days—August 1–15 inclusive:

Shaft No. 1,	319
" 2,	340
" 3,	94
Total,	753

For a period of fifteen days—August 17–31 inclusive:

Shaft No. 1,	244
" 2,	346
" 3,	96
Total,	686

For a period of fifteen days—September 1–15 inclusive:

Shaft No. 1,	277
" 2,	324
" 3,	98
Total,	699

For a period of fifteen days—September 16–30 inclusive:

Shaft No. 1,	228
" 2,	327
" 3,	89
Total,	644

PLATE XIX.—LINING OF TUNNEL UNDER SHAFT NO. 3.

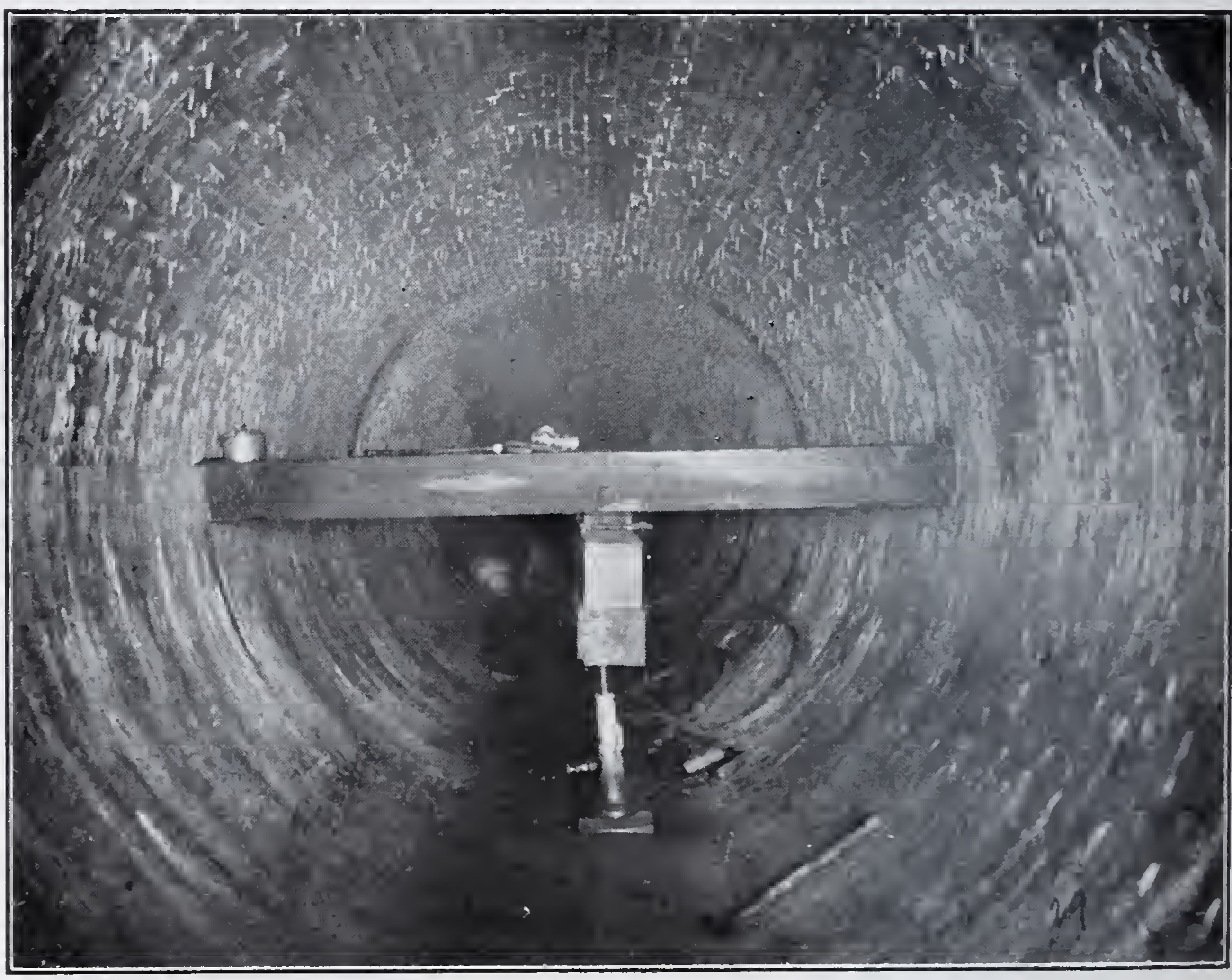


PLATE XX.—CLOSING WEEPER IN INVERT, SHAFT NO. 3.

These gagings were not taken with the precision of those upon which the present leakage of the conduit is based, but are deemed sufficiently accurate for the present purpose, and, comparing these leakages with the leakage for the same sections after the operations connected with the examination and repair of the conduit were completed, viz., 408 gallons per minute, will show a reduction of 44 per cent. A part of this reduction, of course, must be credited to the arching of the tunnel and relieving arches under the working shafts, which, however, would apply only to Shafts Nos. 2 and 3.

Upon closing the working shafts prior to April 8, 1904, readings were promptly taken of the elevation of water in the conduit at Shaft No. 1, and later at Shaft No. 11, when it rose to sufficient height to be gaged from the iron staging in the latter shaft with results as follows:

On April 8 (the first day of gaging) the elevation of water in Shaft No. 1 was 95.467 T. D., or 6.397 feet above the invert of the arch.

By April 18, during a period of ten days, the water had risen to an elevation 182.15 T. D., at which time it was thought that the rate of inflow was too great to be accounted for upon the supposition that the sump at Shaft No. 1 and all weepers had been closed.

Prior to closing the last three working shafts, viz., Nos, 2, 7, and 9, the flow of water from the sump at Shaft No. 1 was very large, and it was thought that, excepting with great care upon the part of the workmen, this sump would not be either effectually or neatly closed, and investigations were, therefore, begun to determine whether the last efforts necessary to reduce the leakage to a minimum had been properly made.

The best gagings previous to closing the last three working shafts (April, 1904) indicated a probable flow of 922 gallons a minute, divided as follows:

Station—Shafts—Headings.	Distance Between Stations, Linear Feet.	Leakage Each Station, Gallons.	Accumulated Leakage, Gallons.
Shaft 9 to 11,	2112.81	42.2	42.2
South 8 to 9,	790.00	17.8	60.0
South 7 to North 9,	1607.50	20.0	80.0
South 6 to North 8,	1593.60	40.0	120.0
South 5 to North 7,	1452.50	92.0	212.0
South 3 to North 6,	2939.29	74.0	286.0
Shaft 2 to North 4,	1952.10	391.0	677.0
Midway 1 and 2 to 2,	675.68	43.0	720.0
Midway 1 and 2 to 1,	675.69	202.0	922.0

Gagings between all the shafts, previous to placing the larger portion of the brick lining and concrete backing, determined by the operation of the pumps at each of the respective shafts, gave leakages as follows:

Shaft. No.	*Gallons per Minute.*
1,	517.50
2,	312.00
3,	367.00
4,	85.00
5,	125.00
6,	120.00
7,	145.00
8,	175.00
9,	110.00
10,	155.00
11,	64.00
	2,175.50

Comparing the last gagings (December, 1904) with these leakages, which generally represent the unrestrained flow of water through the shattered rock after blasting at the headings and benches, the reduction of the inflow of water amounts to about 61.50 per cent.

Considering Shafts Nos. 1, 2, and 3, the gagings made during the first three months of 1903, in advance of the lining of the tunnel, show an average leakage of 1196.50 gallons a minute, and compared to the last gagings taken after the lining was about completed, but before the working shafts were closed (October, 1903), show a reduction of 46 per cent., and compared with the December, 1904, gaging, a reduction of 70 per cent.

Elevation of Ground Water.

While the elevation of ground water has been assumed at 198.00 T. D., or slightly above high tide in the Delaware River along the line of the conduit, the gagings taken last April, after the conduit was closed, and since December 17, when the repairs on the work were completed and the pumps and machinery removed, indicate that this may be too high, and that the mean level of ground water along the line of the conduit is not coincident with or above high tide. Of course, considerable time will be required for the water to attain its normal level, but assuming that it may be 197.00 T. D., then the difference between the maximum elevation of water in Shaft No. 1 and ground water will be 10 feet—*i. e.*, the head on the inside of the

Plate XXI.—Lining of Tunnel under Shaft No. 4.

Plate XXII.—Lining of Tunnel under Shaft No. 5.

conduit will be 10 feet greater than the water in the drift and rock on the outside of the conduit.

At elevation 190.00 T. D., or 7 feet below probable normal elevation of ground water, the known leakage into the conduit since the sumps and open weepers have been closed, and particularly bad spots in the roof grouted under pressure, was at the rate of 65 gallons a minute; and, reasoning by analogy that when the water in the conduit is at mean elevation, Shafts No. 1 to No. 11, of 202.70 T. D., or 5.7 feet above assumed elevation of ground water, the leakage would be no greater, it would then appear that the daily leakage will not be in excess of 93,600 gallons, or, say, 100,000 gallons a day, an amount which would readily be allowed for an equivalent system of cast-iron pipes operating under the same conditions.

Watertightness.

In preparing the plans and specifications the term "watertightness" was frequently used. This was meant watertightness within the limitations of the materials to be used in lining the permanent shafts and tunnel, and no arbitrary leakage was fixed in the specification, because it was not possible, in advance of driving the headings, to make an accurate calculation of the amount of water that would be encountered. It was known from the diamond drill borings along the line of the work that water would be found in the drift and rock at certain depths, and an effort was made to show at what depth water would be found, and to indicate whether the flow was large or otherwise. The diamond drill borings that preceded the preparation of the plans for the work were conducted not so much, however, to determine the presence of water in the rock as to indicate the character of the rock, and to furnish data upon which to fix the center line of the tunnel.

Considering the elevation of the center line of the conduit with reference to sea-level or mean tide in the Delaware River, it should be obvious that the rock was bound to contain a considerable volume of water, and that when headings were driven into it, a flow would be encountered, the quantity of which, however, could not be determined in advance. In close-grained rock, without fissures, and with little injury to seams in blasting, the flow would naturally be much less than if the rock was porous, heavily fissured, and considerably disturbed in carrying on the operations of tunneling. Therefore it was

impossible, at the time the specification was prepared, to indicate any standard for leakage, but the intention was to reduce this to the least possible quantity in a brick-lined tunnel and shafts, thoroughly backed with first-class concrete.

Considering that the mean center line of the tunnel is over 100 feet below ground level, and about 100 feet below mean tide in the Delaware River, it would scarcely be reasonable to assume absolute watertightness for a work so constructed, nor is there any evidence before me, and I have sought it in records of similar works in this country and abroad, that masonry conduits of this description have ever been even approximately watertight, excepting, as in the case of the Cleveland and Chicago lake tunnels, where they are driven through a tough, impervious blue clay, and, as I am informed, no serious trouble was experienced from ground water during construction.

Under conditions of service, assuming the elevation of the water in Shaft No. 1 as 207.00 T. D., and the elevation of the water in Shaft No. 11 as 198.00 T. D., then the mean elevation of the hydraulic grade line of the conduit will be 202.50 T. D. Taking normal ground water level at 197.00 T. D., the mean unbalanced head throughout the length of the conduit would be $5\frac{1}{2}$ feet. Proportioning the leakages on the square roots of the heads with the conduit in service and with the conduit empty—

$838 \times \frac{\sqrt{5.5}}{\sqrt{103}} =$ 193.60, or say 200 gallons a minute, or 288,000 gallons a day, or less than $\frac{1}{10}$ per cent. of the carrying capacity of the conduit.

It has already been shown that the rate of leakage does not vary as the $\sqrt{}$ of the heads, but as some other function of the head, the value of which, for lack of time, has not been determined. In the absence of an expression which will fit the conditions of rise of water-level and leakage into the conduit such comparisons as will be made with other conduits under pressure will be upon the assumption that the leakage does vary as the square roots of unbalanced heads.

Considering structures which bear a similarity to the Torresdale conduit:

The Jersey City conduit is a structure 8 feet 6 inches internal diameter, lined with concrete. Section 1 has a length of 4600 feet, of which 1600 feet is in tunnel through shale and sandstone, and 3000 feet in open cut. The leakage of this during construction amounted to 134,000 gallons a day of twenty-four hours.

Plate XXIII.—Lining of Tunnel under Shaft No. 6.

Plate XXIV.—Lining of Tunnel under Shaft No. 7.

Assuming that it was fairly distributed through the entire length of the work, this would give for the length and diameter of the Torresdale conduit—

$$\frac{134{,}000 \times 10.58 \times 14{,}000}{8.5 \times 4600} = 507{,}623 \text{ gallons a day, or } 352.5 \text{ gallons a minute.}$$

Section 4, of the same work, the Watchung Mountain tunnel, 7300 feet long, is constructed entirely in tunnel, probably through the same material as was found in the tunnel operations on Section 1. The leakage of this section was at the rate of about 2,000,000 gallons a day of twenty-four hours, and the corresponding leakage for the Torresdale conduit would be—

$$\frac{2{,}000{,}000 \times 10.58 \times 14{,}000}{8.5 \times 7300} = \begin{array}{l}4{,}774{,}214 \text{ gallons a day of twenty-four hours,} \\ \text{or } 3315.4 \text{ gallons a minute.}\end{array}$$

The head on the ground water in Section 4 of the Jersey City conduit is probably 160 feet, and, correcting the leakage on the square roots of the heads, the corresponding leakage for a tunnel of the length and diameter of the Torresdale conduit, and under the same water head, would be:

$$4{,}774{,}814 \times \frac{\sqrt{103}}{\sqrt{160}} = 3{,}828{,}919 \text{ gallons a day, or } 2659 \text{ gallons a minute.}$$

The New York shaft of the Harlem River conduit has a present leakage of about 300 gallons a minute. This is leakage from the aqueduct shaft to a pump shaft designed for use as a sump, and cannot very well be compared to the Torresdale conduit, because in one case it is a structure under a head, when empty, of over 103 feet, while the other is a shaft having a head varying from 0 to the depth of the shaft. If any attempt was made to compare the depth and diameter of the New York shaft with the length and diameter of the conduit, it would then appear that the allowable conduit leakage would be enormous, as shown hereafter, and it would be better to consider the leakage of the New York shaft in service with the probable leakage of the Torresdale conduit when in service, because the leakage reported for the shaft at the New York end of the Harlem River siphon is service leakage, and not leakage of the empty structure.

Comparing the New York shaft of the Harlem River siphon (which is 12 feet 3 inches in diameter, 318 feet deep) for water depth and diameter with the length and diameter of the Torresdale conduit, and assuming losses of water or leakage proportioned to the square roots

of the respective water heads, we have the following as the corresponding leakage of the conduit.

Wetted surface of Harlem shaft:

$$38.48 \times 318 = 12{,}236.64 \text{ square feet.}$$

Wetted surface of conduit:

$$33.25 \times 14{,}000 = 465{,}500 \text{ square feet.}$$

Ratio of wetted surfaces:

$$\frac{466{,}500}{12{,}236.64} = 38.12$$

Ratio of mean square roots of effective water heads:

$$\frac{\sqrt{103.48}}{\sqrt{141.37}} = \frac{10.17}{11.89} = 0.855$$

and the corresponding leakage of conduit based on Harlem River shaft should be:

$300 \times 38.12 \times 0.855 =$ 9777.78 gallons a minute, or 14,080,000 gallons a day of twenty-four hours.

The Buffalo conduit or intake, which conveys the water from a pier at the head of the Niagara River into the pump-well of the Buffalo pumping station, is a structure blasted through the Niagara limestone, cut to a section about 8 × 8 feet, and unlined. The intake is 1020 feet long, and during construction leaked at the rate of 1,000,000 gallons an hour, or 24,000,000 gallons a day, equivalent to 16,667 gallons a minute. The tunnel is about 65 feet below the surface of the ground, and probably about 60 feet below the level of water in the Niagara River.

Omitting the large flow of water mentioned above, which came from another source than the river, the leakage was said to be very small—not over 500 gallons a minute when the tunnel was empty or pumped out. Of course, when the tunnel was filled there was probably no leakage at all, because the pressure of water inside and outside would be quite the same.

Neglecting the difference of sections and effective heads of water, and proportioning leakage on lengths only, and assuming the least recorded leakage, the Buffalo conduit for a length equal to the Torresdale conduit, both considered as empty structures, should have leaked at the rate of 6,863 gallons a minute, or at about eight times the rate of known leakage for the empty Torresdale conduit.

Plate XXV.—Lining of Tunnel under Shaft No. 8.

Plate XXVI.—Lining of Tunnel under Shaft No. 9.

During the year 1903, *Atlantic City, New Jersey,* laid a wood stave pipe, 42 inches in diameter, 9807.4 feet long. This was tested for watertightness when completed under 10 pounds' pressure, and gave a leakage at the rate of 78 gallons a minute.

Comparing this to the Torresdale conduit, and assuming the leakage to bear some relation to the internal surface of the pipe and conduit, and that it should be proportioned on the square roots of the respective heads, then the leakage for the Torresdale conduit compared to the Atlantic City wood stave pipe would be 164.25 a minute.

A wood stave pipe should be as tight as a steel riveted pipe, and should represent the minimum leakage for water-carrying conduits, and yet it is evident that this leakage, under the conditions of test (which I understand are substantially the conditions of service), is greater than the service leakage anticipated for the bricklined Torresdale conduit.

An equivalent in carrying capacity of the Torresdale conduit, as stated heretofore, would be 38.8 miles of 48-inch cast-iron pipe. An allowable leakage of 10,000 gallons per mile per day of 48-inch pipe under a pressure of 50 pounds per square inch has been a standard to which the Bureau of Filtration has endeavored to lay the various water-pipes about filters and reservoirs and in the distribution systems, and assuming this value to apply to the lines of cast-iron water pipe which would have been required to balance in carrying capacity the Torresdale conduit, the daily leakage then would be 388,000 gallons a day. The pressure on the empty conduit amounts to about 44.61 pounds per square inch, and, proportioning this upon the square roots of the pressures, an allowable daily leakage for the conduit empty compared to cast-iron lead-jointed pipes, made up in 12-foot lengths, would be:

$$\frac{388{,}000 \times 6.679}{7.071} = 366{,}448 \text{ gallons a day.}$$

The leakage of cast-iron pipe is presumed to occur only at the joints, which are spaced about 12 feet apart. In the case of the conduit, however, every brick in the lining is surrounded by a mortar joint, and if the leakage of cast-iron pipe is reduced to the leakage per linear foot of joint, and then compared with the leakage per linear foot of mortar joints in the intrados of the invert and arch of the conduit, we will have the following result:

Linear feet of lead joint per mile of cast-iron pipe:

$$\frac{48 + 2.5 \times 3.1416 \times 5280}{12 \times 12} = 5817.2 \text{ feet.}$$

Allowing 10,000 gallons leakage per day per mile:

$$\frac{10{,}000}{5817.2} = 1.719 \text{ gallons per linear foot of lead joint.}$$

The mortar joint per linear foot of conduit is 49.873 feet for the circular joints, and 159.60 feet for the axial joints, or a total of 209.47 linear feet.

Taking the leakage of the conduit empty as 838 gallons a minute, or 1,207,000 gallons a day of twenty-four hours, and proportioning the leakage on the square roots of the pressures; 50 pounds for the cast-iron pipe, and 43 pounds (in round numbers) for the empty conduit, then the leakage per linear foot of joint in the conduit will be:

$$\frac{1{,}207{,}000}{209.47 \times 14{,}000} \times \sqrt{\frac{50}{43}} = 0.44 \text{ gallons,}$$

and the ratio of leakage per linear foot of joint:

$$\frac{1.719}{.44} = \text{about } 4.$$

Considering the two classes of structures—one with joints everywhere throughout its length and circumference, and the other with joints occurring only at intervals of 12 feet—this is an interesting if not the correct method of comparison.

The gagings for the return of ground water to the conduit since December 16 indicate that at elevation 190.00, which is 7 or 8 feet below normal ground water level, the leakage was practically nil, or, from the records, less than 40 gallons a minute, showing that the theory of flow upon the square roots of the unbalanced heads will not apply.

Moreover, if it be assumed that the leakage upward for an unbalanced head of 7 or 8 feet would be no greater than the inward leakage for the same difference of heads between the water in the conduit and the water in the rock, the leakage then under conditions of service should be even less than the amount above mentioned. Of course, exactness in this cannot be stated at the present time, nor until the conduit is in service and exact gagings made based upon the displacement of the pumps at Lardner's Point.

The probabilities are that the leakage with the conduit in service

Plate XXVII.—Lining of Tunnel under Shaft No. 10.

Plate XXVIII.—Lining of Tunnel at foot of Shaft No. 11.

will be so small that the most accurate system of gaging for the water flowing into Shaft No. 1, and for the water flowing out of Shaft No. 11, would not indicate a difference—*i. e.*, the relation of 40 gallons a minute to 300,000,000 gallons a day, or 208,333 gallons a minute, is such that the best known methods of gaging would not show a loss of $\frac{2}{100}$ of 1 per cent. of the flowing capacity between the two ends of the conduit. Even if the loss were as high as 200 gallons a minute, as figured on the basis of the square roots of heads, it would only be five times this quantity, or $\frac{1}{10}$ of 1 per cent. of the flowing capacity of the conduit, an amount entirely too small to be indicated with any method of gaging the flow of the conduit which could be conveniently applied.

As interesting data upon the leakage of water-pipes, which bear some relation to the Torresdale conduit, Mr. Brush reports, in the "Transactions of the American Society of Civil Engineers for 1888," sixteen miles of cast-iron main, varying from 4 to 20 inches in diameter, laid after the usual manner, as having a leakage of 750,000 gallons a day, or 47,000 gallons per day per mile. This I should regard as a very large leakage, considering the size of the pipe.

He also reports for 11 miles of 24-inch main a leakage of 70,000 gallons a day, or 6,364 gallons a mile, equivalent to 12,728 gallons per mile per day for 48-inch pipe. This leakage is in excess of that allowed for cast-iron pipe under the rules of the Bureau of Filtration.

Mr. Loweth, in the "Transactions of the American Society of Civil Engineers for 1897," reports a 10-inch pipe leaking at the rate of 600 to 800 gallons a day, equivalent to 3,360 gallons per day per mile of 48-inch pipe. I do not remember that the narrator locates this pipe, nor that the figures given are the results of test. My impression is that this is what he would regard as an allowable leakage for such a pipe.

Mr. John R. Freeman, in his report to the city controller on the water supply of New York, gave as data attained from Fall River, 85 miles of mains under from 80 to 120 pounds' pressure per square inch, with a leakage of 850,000 gallons a day. This includes not only the water-pipes, but the plumbing fixtures, and is equivalent to 10,000 gallons per day per mile of pipe. Since the larger percentage of this pipe is under 24-inch diameter, it is apparent that the leakage is excessive.

In the same report Mr. Freeman mentions Woonsocket, Rhode Island, with 45 miles of cast-iron mains, under 80 pounds' pressure

per square inch, and a leakage of 218,400 gallons a day, including plumbing fixtures, equivalent to 4,853 gallons per day per mile of pipe. Considering that these pipes probably range from 4 to 24 inches in diameter, this leakage is excessive.

Professor Gardner S. Williams, in the "Transactions of the American Society of Civil Engineers for 1897," gives, from his experience in the Detroit Water Works, for a system of pipe 4, 6, and 10 inches in diameter, average diameter, 6.06 inches, 20,607 feet long, a leakage under 90 pounds' pressure of 599 cubic feet in twelve hours, equivalent to 8,961 gallons a day, or 2,300 gallons a mile. Relating this to a 48-inch main would produce a leakage of 18,210 gallons per day per mile under the stated pressure.

A line of 10-inch pipe embraced in the above system of pipe, 3,487 feet long, under a pressure of 42 to 43 pounds per square inch, leaked at the rate of 745 gallons a day, or 1,128 gallons per day per mile, equivalent to 5,414 gallons per day per mile for 48-inch pipe.

The leakage of the Delaware River connections, gate chambers, and pump well, on Contract No. 29, Lardner's Point Pumping Station No. 2, upon test amounted to 15.6 gallons a minute. Reducing this, based upon lengths and with respect to the very considerable difference in pressures, the allowable leakage for the Torresdale conduit would be 336 gallons a minute. The structures, however, at Lardner's Point were all built in open cut, and were kept dry during the process of building, conditions much more favorable for watertight work than were those found in the construction of the conduit.

Proposed Steel Tube Lining.

It has been suggested that the conduit might have been lined with a steel tube instead of bricks laid in cement mortar. In such cases probably the steel would have been made up in segments with circular and radial angle iron flanges bolted together on the inside, and the two finished internally with a ring of fine concrete or mixture of cement and sand, say 4½ inches radial thickness.

Such construction would have increased the cost of the work by quite 100 per cent., and the annual interest charge at 3½ per cent. on $1,274,000 would have been $44,590, or, assuming it to have been possible to make such construction absolutely watertight, about seven times the annual value of the filtered water lost by leakage of the brick-lined conduit.

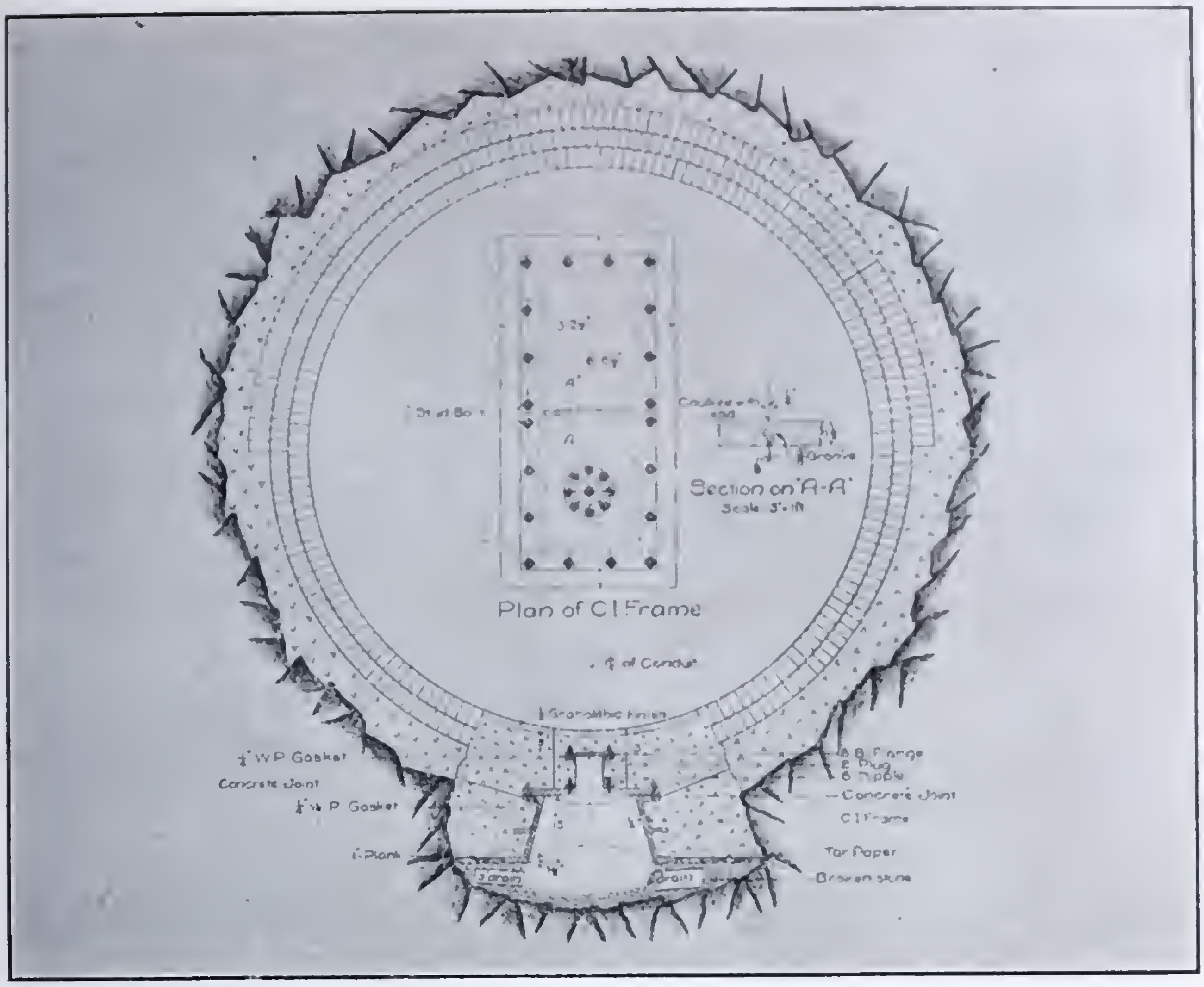


PLATE XXIX.—METHOD OF CLOSING SUMP, SHAFT NO. 1.

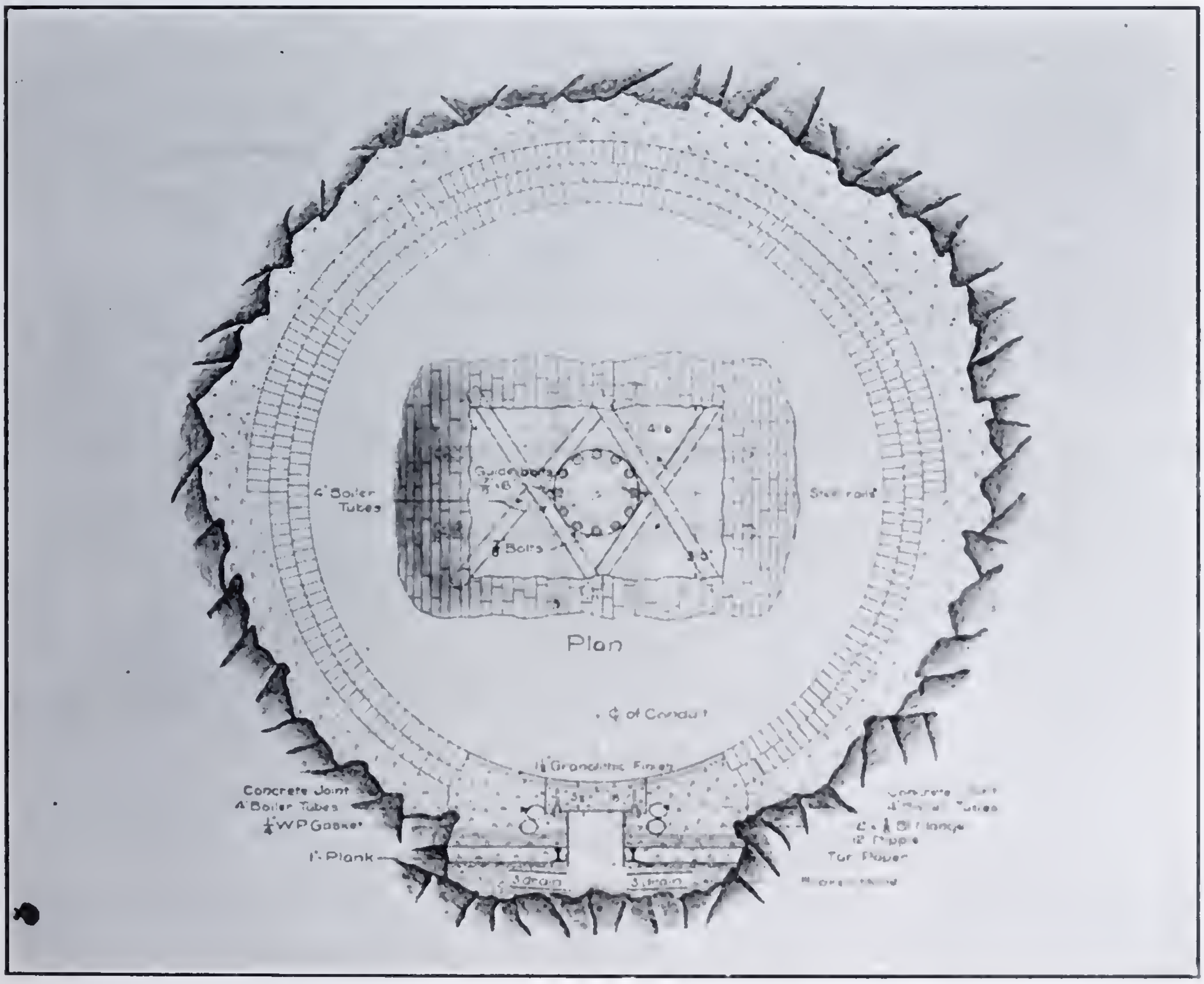


PLATE XXX.—METHOD OF CLOSING SUMP, SHAFT NO. 2.

Refuse from Contract No. 29 Found in Shaft No. 11.

Notwithstanding strict orders were given to the contractor for Contract No. 29, Lardner's Point Pumping Station No. 2, that no waste materials from his operations while making connection between Shaft No. 11 and Valve Chambers Nos. 2 and 3, should be allowed to go into Shaft No. 11, upon emptying the conduit over 13 cubic yards of waste material from this contract was found at the foot of the shaft, measuring about two feet in depth over the center of the invert, and tapering to nothing about 50 feet northward in the conduit. Unless the conduit had been emptied, no one would ever have suspected the presence of this material, which consisted of sand, cement, gravel, and similar wastes. The effect of this was to reduce the sectional area of the conduit quite 11.55 square feet, or 13 per cent. of its least sectional area.

Had this material been allowed to remain in the conduit, its carrying capacity would have been seriously reduced, and instead of charging it to the true cause, viz., that of waste material going into it through operations under another contract, it would probably have been charged to the roughness of the interior or to the insufficiency of the formulas employed for the flow of water through large conduits.

This condition, of course, was a revelation when the first inspection trip was made through the conduit after it was pumped out.

A hole was cut in Shaft No. 11, a derrick and hand winch set up, and the material removed by means of a dumping bucket by hand labor, and the conduit left in a perfectly clean condition.

It is probable if there had been no question as to the proper completion of the work by the contractor for the Torresdale conduit (Contract No. 14), and it was known that this material lay at the bottom of Shaft No. 11, excepting it could be removed by the aid of a diver, or by some method of pumping out the material under water, it would have been profitable to have pumped out the conduit solely for the purpose of removing the refuse which came into it from Contract No. 29.

Supposed Disintegration of Cement.

During the past summer, while the conduit was being pumped out for the purpose of examination and correction of any omissions or defects which the emptying of the conduit might reveal, it was suggested by a well-known chemist in this city that there was some

evidence of serious disintegration of the mortar in the brickwork and the concrete. After the conduit was emptied, careful examination was repeatedly made from end to end by myself and several assistants detailed for the purpose, to detect any evidence of disintegration of the mortar in the joints of the brickwork, and no evidence of injury or impairment from any cause was discovered. While considerable lime was removed with the water from the conduit during the process of pumping out, this, after the first few weeks' pumping, steadily diminished until the water attained about the alkalinity or lime content found by analyses of the water from the shafts and headings previous to the placing of the brick lining and concrete backing. The total amount of lime removed with the water amounted to about 50,000 pounds; and this should be balanced against the lime in 35,000 barrels of Portland cement used in the construction of the work. The cement, under the terms of the contract, weighed about 380 pounds to the barrel, of which, say, 62 per cent. by weight was lime, or 8,246,000 pounds; and of the lime from all known sources, not, of course, including the lime found by test in the rock water previous to lining the conduit, about 0.60 per cent. may have come from the mortar in the joints of the brickwork and in the concrete.

I am informed by manufacturers of cement that there is a probable 1 to 1.5 per cent. excess of lime in the mixture—*i. e.*, the amount of lime is usually slightly more than is really required to make a perfect cement. The influence of this upon either the strength or hardening properties of cement is not noticeable, and if it be assumed that there is a slight excess of lime, it would be possible to lose even a larger percentage than was shown by the estimate of lime lost in pumping out the conduit without impairing the quality of either the concrete or the mortar in the brickwork.

Under the conditions of service it is not thought that the slight outward leakage of filtered Delaware River water will have any serious effect on the lime in the cement, and this opinion is based upon long observation of the influence of water low in lime content, like that of Loch Katrine, on the cement plastering and mortar in the joints of the masonry of the first Glasgow aqueduct.

Analyses of Water Flowing into the Shafts and Headings.

During the construction of the work samples of water were collected monthly from the shafts and headings, and analyzed for mineral

content and bacteria. The rock water, as would naturally be supposed, excepting for the considerable amount of iron it carried, was unobjectionable from a sanitary point of view. The bulk of the leakage into the conduit when empty occurred north of Shaft No. 4, or within the first 3,500 feet of tunnel length, at which point, under conditions of service, the pressure of water in the conduit will be greater than the pressure of water in the ground and rock, and the leakage will be of filtered water into the rock and not of rock water into the conduit. The leakage, therefore, does not represent any possible menace to the quality of the water supplied from the Torresdale filters, but does represent a loss of filtered water, the value of which has been previously noted.

Under conditions of service, with the conduit delivering 300,000,000 gallons a day of twenty-four hours, the lowest elevation which it is expected the hydraulic grade line will take in Shaft No. 11, is 198.00 T. D., or about the maximum elevation heretofore noted of ground water along the line of the work. Of course, when the flow is less than 300,000,000 gallons a day, the hydraulic grade line at Shaft No. 11 will be correspondingly higher, and it would be only at such times as the flow is increased to more than 300,000,000 gallons a day, or for some other reason, the hydraulic grade line might be lowered throughout the length of the conduit, that the elevation of the water in Shaft No. 11 would be below that of the ground water, when a small amount of ground water may find its way into the conduit south of Shaft No. 10. Should this occur, no uneasiness need be felt as to its influence on the very large volume of filtered water flowing through the conduit, and indeed it is doubtful if careful technical tests would show any change in the character of the water at Lardner's Point by reason of the small admixture of water from the rock surrounding the conduit.

In closing this paper I take pleasure in acknowledging the faithful and indefatigable labor of Mr. T. Nelson Spencer, first assistant engineer in charge, both of the original construction, and examination and repair of the conduit; and to the work of Mr. Louis R. Snow, official photographer of the Department of Public Works, who took the flash-light photographs in the tunnel and the other pictures, and prepared the slides which have been so useful in illustrating construction features of the Torresdale Conduit.

DISCUSSION.

Chairman.—We have with us this evening a number of visitors from sister cities who are well acquainted with waterworks. Before calling on our visitors, I would like to call on Mr. Ledoux, if he is present, or Mr. Trautwine, who accompanied Mr. Hill in the inspection of the Torresdale conduit.

Mr. Trautwine.—I had the pleasure of accepting Mr. Hill's courtesy in making a trip with him through this conduit a couple of months ago. The conduit was not entirely dry, and there was, in places, I suppose three feet of water, which extended half a mile or so. One of the things which I noticed was the fact that a very large part of the tunnel was, to all appearances, absolutely dry, whereas, roughly guessing, about one-third of the tunnel exhibited all the leakage, which was coming through in places with remarkable freedom—jets spraying out, and in some places a dozen or more coming down from the roof or top, reminding me of a shower-bath. I neglected then to ask a few questions which occurred to me and which I have not since had the opportunity to ask Mr. Hill. One is, Why was that difference in leakage so noticeable at that particular point in the tunnel? Another question was about the wooden plugs which were being driven into the openings and joints of the brickwork, and the object of driving them—no doubt to stop those particular leaks; but it would seem that wherever a leak was stopped the water which could not find efflux there would find its way again in some other place. In the very admirable description of the work which we had this evening one point arose in my mind in connection with one of the views—that where the finished brickwork was shown and also the rock bench in the tunnel work beyond which had not yet been removed—I was wondering to what extent that finished brickwork might be weakened by the blasting of the bench. I do not want to sit down before congratulating not only Mr. Hill for his excellent paper, but also the large meeting of the Engineers' Club and its visitors, of whom I recognize many gentlemen from a distance. I do not think we had many more present on the occasion of our banquet, and a banquet is always an attractive feature.

Mr. Hague (Visitor).—I have listened with a great deal of interest, as I am sure you all have, to the very instructive and methodical description of this tunnel which Mr. Hill has given us to-night. I am familiar with this work only from what I have seen of it casually, and from what I have read in the engineering papers, but the conclusion seems to be that so far as the conduit is concerned, at least, it has approached probably as nearly as it is possible to watertight steel work. Of course, we all know that work of this kind is prosecuted under more or less difficulties—some of them pretty serious and some of them very dangerous. We all know that there are more or less seepage and leakage, and I think that Mr. Hill has summed up in a very practical way the ultimate result to be considered, and that is the cost in money to the city of Philadelphia of this seepage or leakage, which, as he clearly points out, a great many outside engineers may not think of. The leakage in operation will, of course, be the filtered water going out, for the simple reason that the inside head will be greater, and that should remove from the mind of everybody in Philadelphia all alarm or thought of contamination of the water from any leakage that may take place in the tunnel. I had hoped, by the courtesy of Mr. Hill

to take a trip through the tunnel, but I did not get there in time, so missed it. But from what I have seen I have a good and a clear idea of what has been accomplished, and I think we all feel thankful to Mr. Hill for his clear description of this work.

Mr. Allen (Visitor).—This paper is full of interesting points. Among others is the collection Mr. Hill has made of data of seepage through different kinds of conduits, and especially brick conduits of this kind. Data of this kind are difficult to obtain, and not often available, and for that reason I think particularly valuable. We all know how difficult it is to make a watertight sewer; the brickwork almost invariably leaks a large amount of water. In Atlantic City there are three lines of pipe crossing the meadows. Most of you are familiar with the location of the meadows there. These pipes are about five miles in length, and consist of one 12-inch and one 20-inch cast-iron lines, and a line of 30-inch riveted steel pipe. The two cast-iron lines are getting pretty old; they are inspected daily, and there are several hundred leaks stopped a year. Records are kept of them. It may be interesting to mention that a short time ago we estimated the leakage through them, and this is the way we did it: The pipes are all controlled by valves, so that we can shut off any valve and pump up the water through that particular pipe. We had a small pump at the pumping-station—a single-acting pump which we worked at such a rate, with all the valves closed, that the action of the pump simply represented the slip. That was with the valve closed at the station; then, opening the valves at different points on the line, we could get the leakage in that particular section of line by the additional displacement of the plunger, the displacement representing the leakage or slip. In that way we found the amount of leakage by testing each of the three lines. I am sorry that I cannot give you the exact amount, but it was quite considerable in the two cast-iron lines, amounting to several hundred thousands of gallons a day. What that would be in the terms of lineal feet or joints I have not computed. The steel line was nearly tight. There was a very slight leakage shown, but so far as we can tell it was practically a tight line. Mr. Hill referred to the wooden stave pipe built about a year or two ago there. The pressure used in that test was a low pressure,—only ten feet of head (three or four pounds),—but even that is greater than the service pressure. It is merely a conduit for carrying water without pressure, except that of a couple of feet or so. I think that we are all very much indebted to Mr. Hill for the very interesting paper, and as for myself, I am very glad to hear this data on the leakage of pipe, because it is something that has interested me in the last few years.

Mr. Quick (Visitor).—I consider myself under obligations to the members of this Club and to Mr. Hill for the privilege of being here to-night and listening to this extremely interesting description of the Torresdale conduit. It is a revelation to me, and I suppose it must be to a great many other people, to hear of such remarkable and extensive engineering work going on in Philadelphia. I do not think it has been published abroad to the extent that it ought to be, considering the very interesting nature of it. But, as bearing upon the point which Mr. Hill talked about to-night, particularly in relation to leakage of the conduit, it might be interesting to him or to the members of this Club for me to cite an instance which he did not cite in making comparisons with other conduits. We have in Baltimore—our main source of water-supply coming from the Gunpowder

River—a tunnel seven miles long, and, I should judge, built under very similar conditions to this Torresdale conduit—about the same dimensions, built very largely, I should say, about the same average depth below the surface of the ground, and about the same average head of water on the outside and about the same head on the inside, and built in a very similar manner as to the nature of the masonry—about three-fourths of it through solid rock. Of course, this was all built before I was connected with the department, but the records are all available. I do not know how carefully they were taken at the time, but some estimate or measurement was made as to the amount of leakage into that tunnel before it was completed. The cross-sections, as shown here on the screen, might very well represent the Gunpowder conduit of the Baltimore water system, and the leakage as measured flowing into the conduit when empty (not in service) was about 3,000,000 gallons a day, and, I should judge,—I do not know what method Mr. Hill uses in making these comparisons with other conduits, but I should imagine that equalizing the difference in the length of the conduits and the slight difference in the interior diameter,—the exterior head being about the same depth below the ground, the leakage into the Baltimore conduit was just about the same as that in the Torresdale, perhaps a little more—that is, so far as I know, and so far as any records show,—and, so far as subsequent experience has shown, it has given no trouble in any way whatever.

Mr. Baker (Visitor).—I have been very much pleased with and interested in the paper that has been presented here this evening. I am sure that the Club and Mr. Hill are to be congratulated upon having so excellent a description of this noble piece of engineering work, and particularly of the study of the leaks in the conduit, which have been put on record. I think it would be unbecoming for me to attempt to enter into any extended discussion of the paper. I am sure, however, that the various figures which have been presented relating to the leaks in the conduit itself and the description of the method employed to stop the leaks, and the comparisons with leakage in other conduits, are all very valuable, and should, I think, convince any critic that Mr. Hill knows a great deal more about the subject of this leakage than his self-constituted critics of some months ago. As to the criticism itself, I will not venture to speak further than to say that it has appeared to me, as it doubtless has to others, that some of it was pretty severe, as coming from the City of Brotherly Love.

Mr. Quick.—Was there more leakage under the Pennypack Creek than at other points?

Mr. Hill.—About 40 per cent. of the leakage is between shaft No. 1 and shaft No. 3. (Shaft No. 1 is north and shaft No. 2 south of Pennypack Creek, and the principal leakage is between these shafts, but the water from the conduit is sufficiently unlike the creek and river water to suggest that it is coming from another source.) I neglected to state that there were a number of spots found—and Mr. Trautwine noticed some of them—where there was a very large leakage through the roof. In all such places we drilled through the brick arch, inserted a two-inch wrought-iron pipe, and pumped over the arch grout under a pressure of from 90 to 100 pounds per square inch, and, as a rule, the pumping of grout completely stopped the leakage in those overhead spots.

At places where there was no object in pumping through the weeper pipes they were closed very much after the manner of a bunghole in a beer barrel. It

is probable, too, that some of the large weepers that were found open in the neighborhood of shaft No. 2 were open by reason of the plugs not having been properly driven. We found in the débris in the bottom of the conduit some loose plugs, but could not ascertain positively whether or not they had ever been driven into the weeper pipes. Where the leakage was large the joints in the brickwork were closed with white pine wedges; the joints were opened with a narrow chisel, and the space then filled with the plugs, which were either driven in flush with the face of the brickwork or had the excess trimmed off flush.

Mr. Trautwine.—About the matter of finished brickwork being damaged by blasting close to a finished section, as shown by the views.

Mr. Hill.—The actual distance between the brick lining and the bench shown in the picture is probably 40 feet. Before the blasting operations were conducted at that point a timber bulkhead was put up near the finished lining, so that the flying rock would not damage the work.

Mr. Trautwine.—Is it not very probable that there was a transmission of shock through the walls of the tunnel?

Mr. Hill.—There was no evidence of it. I am quite sure that no damage was done to the finished lining by subsequent blasting operations.

Mr. Edwin F. Smith.—Mr. Hill has given us a most interesting paper—full of interest, I think, not only to members of the Engineers' Club of Philadelphia, but, I may say, I am sure to the large number of visitors who have honored the Club with their presence. The hour is growing late, and I shall not detain you. But there is one point upon which I should like to say a few words, and that is bearing upon the statement made by Mr. Hill that it is exceedingly difficult to construct such conduits so as to make them entirely watertight. I have been engaged in the construction of hydraulic works at intervals for forty years, and I know how difficult it is to carry any such work to completion without accident or fault of any kind whatever. We have to depend upon our workmen; we must depend upon foremen; we must depend upon supervision in one way or another, and sometimes things occur that we do not look for. Even when there is no accident whatever to the work in any part of its construction it is an impossibility to construct any such work as the Torresdale conduit and make it perfectly watertight. From the discussions which we have seen in public prints the people of Philadelphia would most certainly be led to believe that such works over all the world, wherever they may have been constructed, are perfectly watertight, and that the city of Philadelphia should expect that the Torresdale conduit should be perfectly watertight. Now, that is an impossibility. As to lining conduits of this construction, it would be simply a waste of money for the city of Philadelphia to put into such a conduit a cast-iron lining or steel lining. It is not necessary; it is not called for. It is not done where works are undertaken to be constructed in an economical way. It is not done in crossing under the Harlem River. It has not been done except in rare instances. It will, I believe, be done in the tunnel under the East River, which, however, is intended for an entirely different purpose, namely, carrying passenger trains, where the railroad company will go to a great expense to keep the tunnel dry. But it is not necessary in a conduit for the conveyance of water. It is only economical up to the point where sufficient money could be saved in prevention of seepage of water to cover the cost of interest on the investment, perhaps. But in the

case of the Torresdale conduit, it would be an unnecessary thing to do and a waste of money. Now, I have often said to my friends that when this plant was completed it would be one of the finest pieces of work in the world, and I do not see any reason for changing my mind up to the present time. It is a great work,—a peculiar and difficult task,—the filtration of so vast a quantity of water, and the work has been splendidly done. We have before us the exhibit of the Roxborough filtration plant and the partially completed Torresdale plant, and this Torresdale conduit, and I do not hesitate to say, before the engineers of the Club, with my knowledge of hydraulic work, that they are all well built, and will serve their purpose for generations. I think that we are under obligations to Mr. Hill for making this work so clear to us; we understand its technicalities, and we appreciate Mr. Hill's kindness in coming before us with this paper. I, therefore, Mr. President, move that the thanks of the Engineers' Club of Philadelphia be voted to Mr. Hill for his most interesting paper on this great work, the Torresdale conduit. (Applause.)

(Carried.)

COMMUNICATED DISCUSSION.

Mr. Alfred M. Quick.—The conduit to which I referred is the conduit which carries water from Loch Raven, the impounding reservoir on the Gunpowder River, our chief source of supply, to Lake Montebello and Lake Clifton, the distributing reservoirs in the city. It is seven miles long, and has a fall of one foot to the mile, and its capacity under a normal seven-foot head is 170,000,000 gallons of water a day.

The brickwork of this conduit is laid in cement, in normal cross-section of two rings in invert and three in the arch, and where the ground was bad one or two additional rings were put in. The tunnel is laid under the surface from 36 to 354 feet deep. The estimated leakage of the tunnel is 3,000,000 gallons a day; this being on the basis of a gaging made shortly after the tunnel was built.

Mr. Kenneth Allen.—The water-supply for Atlantic City is pumped across the "meadows" from Absecon through three mains: a 12-inch cast-iron pipe laid in 1882, a 20-inch cast-iron pipe laid in 1886, and a 30-inch steel main laid in 1901. The distance from the pumping station to the submerged crossing of Beach Thoroughfare, near the city, is 25,200 feet. Cross connections with valves between the three mains are placed at intervals of about a mile. Near the pumping station is a 30-inch Venturi meter through which the entire supply flows.

These mains, being on the soft meadow mud and the older ones having deteriorated by the vegetable acids and the salt water saturating the soil, are laid just below the surface and are inspected daily, except Saturdays and holidays, by a man who repairs such leaks as are discovered. During the year ending September 1, 254 leaks were stopped on the 12-inch main, 171 on the 20-inch main, and 17 on the 30-inch main. Of the latter, 15 were at slip joints and 2 at rivets.

The total leakage on the two cast-iron mains is naturally considerable, and we have attempted to discover the approximate amount of this in the following way:

Cutting off the force mains by a valve on the discharge a 1,000,000 gallon non-condensing Worthington pump was run with throttled steam, so that the

normal pressure of about 50 pounds per square inch was maintained, when the calculated displacement was assumed to equal the slip during ordinary operation.

The three mains were then opened up in succession as far as a valve near Beach Thoroughfare, 4.75 miles from the station, and the pump operated at such speed that the same pressure was maintained as before. The difference in the displacement observed, less the slip as previously found, was assumed to represent the leakage in each main. This, in gallons per day, was found to be:

For the 12-inch main,	491,000	gallons,	or	103,300	gallons per mile.
" " 20 " "	386,000	"	"	81,300	" " "
" " 30 " "	55,000	"	"	11,600	" " "

HENRY H. QUIMBY.—Referring to the rate of leakage under different pressures, it may be that the rule of variation as the square root of the pressure, which is used in the paper as the basis for computation of the probable leakage of the conduit in service, fairly applies to orifices not too minute to permit a liquid to pass through at some speed, however slow, at any pressure, however slight, but it cannot be applied to leakage due to mere porosity of materials, because pores may be developed under high pressure where the material is absolutely impervious at lower pressure. The writer has made many tests of iron, brass, and aluminum for porosity, and found that where porosity existed in metal without visible flaws and perfectly sound in appearance of texture, it developed only under some considerable pressure. Metal that would hold for days a constant pressure, as shown by a sensitive mercury gage, might, upon increasing the pressure, show leakage at some point or points, and at additional points upon still further increasing the pressure. Instances occurred where very much greater pressure (always internal) actually reduced the quantity of leakage or even stopped it altogether, perhaps indicating that the natural law governing such phenomena operates with nodal points of reversal resembling the vibrations of a rod or the changes of volume of water from temperature. Water was used in testing brass and aluminum, and either water or mercury for iron. Observation without measurement of quantities led to the conclusion that the leakage from porosity increased much faster than directly as the pressure, though evidently not so fast as the square of the pressure. The opening of additional pores under increased internal pressure may be due to an infinitesimal yielding of the material stressed in tension, but in the case of the conduit, the fact that the concrete backing has not had and never will have an opportunity to dry out, but will be perpetually saturated, will probably prevent any shrinkage and insure so firm a pressure against the rock that the element of distention will not become a factor.

What percentage of the infiltration observed in the conduit is chargeable to a quality of porosity, and therefore likely to diminish directly as or faster than the pressure, or stop altogether, is hardly guessable, but is probably considerable, and the logical conclusion is, therefore, that the outward leakage under the slight service head will be less than the paper assumes, even if there should be no clogging of the pores by matter that may possibly be carried into them by even filtered water.

Mr. Hill.—Reducing the Baltimore tunnel data to the Torresdale conduit basis, we have the following results as leakage per day of twenty-four hours:

$$\frac{3{,}000{,}000 \times 2.65 \times 10.58}{7 \times 12} = 1{,}001{,}309 \text{ gallons.}$$

While the leakage, under similar conditions, of the Torresdale conduit, by the latest gagings, December, 1904, was:

$$838 \times 1440 = 1{,}206{,}720 \text{ gallons.}$$

Mr. Hill.—Reducing the Atlantic City leakages to losses for 48-inch pipe per day per mile, they become:

Based	on	leakage	of	12-inch	main,	413,200	gallons.
"	"	"	"	20 "	"	195,120	"
"	"	"	"	30 "	"	18,560	"

It will be remembered that the limit of leakage for 48-inch pipe tested after laying, under 50 pounds' pressure, under the rules of the Bureau of Filtration, is 10,000 gallons per day per mile.

The practical result of Mr. Quimby's theory of seepage, or leakage, is shown in tests for watertightness of lines of cast-iron lead-jointed pipes; at low pressures no leakage is sometimes observed, while at test pressure the leakage becomes a measurable quantity. Also in testing stop valves for watertightness; these are frequently tight at 125 to 150 pounds' pressure per square inch, and leak at a measurable rate when subjected to higher pressures. Of course, leakage based on the square roots of heads will not apply in such examples, and the same condition is probably true of the conduit under low differences of internal and external pressures.

DESIGN AND OPERATION OF A MODERN FREIGHT YARD.

JOSEPH T. RICHARDS.

Read February 18, 1905.

The increasing population, agriculture, manufactures, commerce, and wealth of the United States naturally cause a rapid increase in the traffic thrown upon the railroads for transportation; particularly is this so from the growing west to the east, and burdens the railroads to such an extent that it seems almost impracticable to construct railroad tracks, yards, and terminal facilities fast enough to keep pace with the increased business. It is evident that all the trunk lines east of the Mississippi are behind in their tracks, terminals, and equipment to move and distribute the tonnage of freight offered them.

The Inter-State Commerce Commissioners' report for the fiscal year ending June 30, 1903, which is the latest report which has been issued, shows an increase of 104,078,536 tons of freight carried over the previous year. The total tons of freight carried were 1,304,394,323, the increase in one year being 8.7 per cent. of the total. The aggregate number of freight locomotives in service was 25,444, an increase of 1850 over the previous year, being 7.8 per cent. of the total. Freight cars in service, 1,653,782, an increase of 107,681 during the year, being 6.9 per cent. of the total. Total mileage of railroads in the United States was 207,977.22, an increase of 5,505.37 miles for the year, or 2.7 per cent. of the total.

From this is shown the increase of miles of road (2.7 per cent.), which is given for both freight and passenger service, is low in increase as compared with increased tonnage of trade pressing into the channels of transportation (8.7 per cent.)—about 3 to 1.

The cars and locomotives are also low, but not so seriously behind as is shown in the lack of trackage. As to the matter of terminals and yard facilities, I have no data to be taken from the reports of the Inter-State Commerce Commission, but they bear quite as important a part as any of the other factors in clearing the channels and adding to the ability of railroads to move freight from end to end of the roads. Through yards are the working facilities *en route,* and the terminal yards are the working facilities at the end—particularly are the ter-

minals at large cities and when the road ends at the Atlantic seaboard. More especially is the New York harbor the greatest of all to be considered, for the reason that, like Rome, none of the roads run through.

For the terminal in New York harbor you can very well imagine the immense tonnage of freight accumulated by the trunk lines in all the district east of the Mississippi, as you see the busy freight trains moving east and coming to a sudden stop at the waters of New York Bay—the task the railroad men have of distributing and unloading cars, some to the piers of New York, others to steamships for export to foreign ports, and others to be transferred by water, to be forwarded to New England. All these cars are to be classified and returned to the west, and so the business continues, increasing about 10 per cent. a year, and keeping the railroad companies hard up to the task of providing a terminal to prevent a congestion of their share of the trade at this most important harbor.

For an inland terminal I will give you a short statement of freight increase in the city of Washington. In eight years the freight business handled by P. B. & W. R. R. has increased 110 per cent. The business taken care of by the P. B. & W. R. R. coming into Washington from southern lines shows that C. & O. freight has increased in eight years 350 per cent., and from the Southern Railway and Atlantic Coast Line in eight years the increase has been 650 per cent.

It has not been possible for our railroad facilities at this place to keep pace with this increased business, and you can well understand how serious the matter of freight and passenger congestion must have been in this city when the P. R. R. and the B. & O. have arranged to spend not less than $7,000,000 to rearrange tracks and terminals and put themselves in position to meet the situation. This is only one of a number of instances that might be mentioned to show the increased tonnage thrown onto the railroads by the growth of the country.

I will now consider a plan for a general yard design and the method of operating it. The proper function of this yard is to pass cars *en route* through within the least possible *time*. In common practice yards have their names: A. The receiving yard. B. The classification yard. C. The departure yard. D. The gravity yard—long continuous grade. E. The poling yard—but little if any grade. F. The summit yard (hump) and others of minor importance.

It may be well to state that the ideal railroad is said to be one that has no yards; that is, a train can start at one end and run through to the other without classification. This can be carried out for a great

deal of traffic for a railroad, say 100 miles long, but where the length multiplies and the line becomes as long as trunk lines in the United States (we may say from the east to Chicago), it is necessary to change engines and make classification of cars. Therefore the yards come in as a necessary evil. It is a question, then, how to arrange these yards to make the least possible delay, as time in transit is the most important element that railroad transportation and traffic managers have to consider.

We will trace the progress of a freight train coming into and through the several parts of this general freight yard. The train arrives from the road, and, in passing into the receiving yard, the cabin in the rear is cut off, on the lead track, at the switch, leading to the cabin yard; the road engine continues with the train into the receiving yard, and, upon arrival there, cuts loose and goes directly to the engine yard; the cabin, in the meanwhile, having drifted into the cabin yard into a position ready to go out on the road in the opposite direction in its proper turn, the cabin tracks being graded to accomplish this movement. As soon as possible after arrival in receiving yard the train is inspected, the destination in the classification yard of the various cars is marked upon them, as well as the needed repairs to crippled cars which are to be thrown off into a separate track, known as a cripple track, and finally taken to the car repair yard. When the train is ready for classification, a pusher engine gets behind it and gradually pushes it over the "hump," the speed being about six miles an hour. As the cars pass over the "hump," a man stationed there, and known as the "cutter," separates them into "cuts," of from one to ten cars.

In marking the cars for classifications each "cut" of a draft or train is marked with its destination at the front end and the destination of the next succeeding "cut" at the rear end. This is for the benefit of the man in the tower operating the switches, so that he will have sufficient time to set the switches for each "cut" as it comes along. He is also furnished with a check list of each draft or train showing the "cuts" to be made, and the number of cars in each "cut."

The towerman in a two-story tower adjacent to the "hump," from which he can see the entire layout, operates the switches electrically by means of a push button machine, so that the cars will pass to the proper classification tracks. The speed at which the train is pushed over the "hump" is such that the cars, in running away from the "hump," usually are separated a sufficient distance from each other,

that they will not foul one another when passing over the ladders, but in the event of too many "cuts" following the same ladder and thus getting too close, the tower is equipped with an air-whistle or other signal under control of the towerman, by which he can regulate the speed movement of the pushing train. When a sufficient number of cars have accumulated in the classification yard (say, a train length) for any particular destination, or should the tracks of this yard become full, the cars are pushed out into the advance tracks or starting yard, where they are coupled up into trains and the air tests made. A road engine which has moved from the engine storage tracks couples up to the cars as they stand on the advance tracks, and pulls the train out on the main track, and in passing by the cabin yard a cabin is dropped out by gravity and coupled up to the rear of the train. The above process applies to trains in both directions through the yard. The cars pass over the "hump" at the rate of about eight a minute under ordinary conditions. To pass a freight train of, say, 80 cars through a yard as above stated, from the time of entering the receiving yard to leaving the departing yard, should not require more than two or three hours.

We will now follow the incoming road engine after it leaves the train in the receiving yard. It first passes to the inspection pit, where a thorough inspection is given it, and, if repairs are necessary, a message is sent to the round-house that engine No —— will be placed in the round-house for certain repairs. This gives the round-house foreman an opportunity to have a stall ready to receive this engine. The inspection requires about five minutes. From the inspection pit the engine passes on to the ash pit, where the fires and the front end are cleaned, requiring, on the average, thirty minutes. The engine then passes alongside the coal wharf, where it receives its coal, taking up about one and one-half minutes; sand is then taken on at the far end of the coal wharf, and water at this same point. It takes from 1 to 2 minutes to fill the tank with water with the proper size standpipe. The engine then passes to the turntable, and, if it is to be housed for repairs, it is placed in the round-house. If no repairs are necessary, it is turned quickly and sent direct to the engine storage yard, where it awaits a call for power for a return train on the division from which it arrived. The average total time taken by an engine, where no repairs are made, from when it cuts loose from its train in the receiving yard until it is ready to take a train out on the road again, whould not exceed one and one-half hours in a properly arranged yard. When

a yard plan is not properly planned, an engine will take from four to six hours to make the same movement.

DISCUSSION.

Mr. C. M. Mills.—What does the mark you place on the cars indicate? Does it indicate the track on which they are to go?

Mr. Richards.—Yes, the tracks are all numbered, and the mark on the car indicates the track to which they go.

Mr. Mills.—What kind of a mark is it? Is it a placard?

Mr. Richards.—No, they are generally chalked plainly on the side of the car. The man in the tower has a card list, and the "cuts" that are made of the train in the receiving yard are all placed on this card. The cards are delivered to the man in the tower, and they show him what is coming. Then, as the cars come along to the hump, he watches his card and watches his cars.

Mr. Mills.—Are the numbers of the cars put on the cards he gets?

Mr. Richards.—Yes, they are.

Mr. Furber.—Is that necessary? You have the number of cars on every "cut" and the number of "cuts" to be made. Suppose you wish to make 60 "cuts," do you have to have a man with each?

Mr. Richards.—Yes, the card is necessary. As to the number of men—one man can take 10 cars or one car. If there were 10 cuts in 60 cars, there would have to be 10 men, and if there were 60 "cuts," there would have to be 60 men, unless some of the first cut men would return to the hump and take a second trip; this generally is the case, and not so many men are employed. This yard from the hump is very steep; it starts about two feet to the hundred. That carries the car through the switches, and when it gets down to the easy grade of the classification yard, the man knows about where it will stop, from his experience, and gets off to return. There is often employed a small engine with a car that runs him back to save time.

Mr. Furber.—Will you describe the button-controlled switches? Have they been in use very long?

Mr. Richards.—That method is somewhat cheaper than a full interlocking system with signals. It is simply an electric button which actuates a valve and throws the switches. They call it a button machine because the switches are thrown by pressing a button instead of by throwing a lever. It is not necessary to have signals. The device is not a new one.

A Member.—Do you use spring frogs or stiff frogs?

Mr. Richards.—We use both, but generally a frog that springs both wings; it gives a better opening for wheel flanges to pass through.

Mr. Furber.—In the case of a car getting on the wrong track, how would you correct the mistake?

Mr. Richards.—It would have to be shifted back if it got on the wrong track; this sometimes will happen.

Mr. McClellan.—But if a "cut" has a number on it and the towerman wishes to know the destination of the "cut" following it, is there anything else shown on that "cut" so that he can check it?


To Washington
North Bound Advance Tracks
South Bound Freight Track
North Bound Pass'r Track
South Bound Pass'r Track
North-Bound Fast Freight Pull-Out Tracks
North Bound Classification Tracks
N.B. Cabin Tracks
Engines In
South-Bound Receiving Tracks
Scale
North-Bound Passenger Track
South Bound Passenger Track
North-Bound Fast Freight Receiving Tracks
North Bound Receiving Tracks
Power House
Transfer
Shed
S.B. Engine Storage
Thorofare Track
South-Bound Classification Tracks
Repair Tracks
Pl. Mill
Thorofare Track
South Bound Advance Tracks
Cabin Tracks
North-Bound Freight Track
S.B. Freight Track
To Richmond
Washington Southern Ry.
PLAN OF FREIGHT YARD
NORTH OF
ALEXANDRIA, VA.
Scale
May 9-1904
Joseph T. Richards.
Chief Engr. M. of W. R.R.R.

Mr. Richards.—Yes, each "cut" shows its destination as well as the destination of the "cut" following it.

Mr. McClellan.—Then are there two marks on each "cut"?

Mr. Richards.—Yes; each "cut" should have two marks, and on both sides of the coupling the numbers should be the same.

Mr. McClellan.—Does not the location of the engine facilities in this yard favor the engines entering the yard in one direction at the expense of those entering from the other direction?

Mr. Richards.—That makes but little difference. It is *not* so much the distance the engine runs as the importance of having a separate engine track for engine run. They get home quickly if there is no interference.

Mr. Nichols.—Do you always locate the engine facilities between the two different yards?

Mr. Richards.—Not always, but generally so as to save crossing. If property or physical reasons compelled us to go outside, we would try to get the engine tracks under the main running tracks to give the engines a quick and uninterrupted run. The cardinal consideration in designing a modern yard is time.

Mr. Nichols.—What is the length of that yard?

Mr. Richards.—About two miles, from end to end.

Mr. Little.—Would increasing the facilities in the future, adding more tracks, change the whole system?

Mr. Richards.—No; we have provided for the future. There is only half of this yard to be constructed at this time, and we have room to about double it. The dotted portion represents future extensions.

Mr. Little.—In the event of a larger space to be provided for, would you have to shove the passenger tracks out? Would the classification yard then be extended down?

Mr. Richards.—Yes; after all the dotted portion is completed we would then move the classification tracks over. We have, however, provided quite liberally, having in the receiving yard a large area. In the classification yard we have not quite so much, although we have three tracks on the side and could put in three more. It is, of course, always well to provide for future extensions.

Mr. Wilson.—How thorough is the inspection of cars in the several yards?

Mr. Richards.—When the train arrives, all cars are inspected in the receiving yard, and again in the starting yard. The engines are thoroughly inspected, and if anything appears to be wrong, it is reported, and the engine sent into the round-house. If no repairs are necessary, the engine is turned and takes another train.

Mr. Furber.—Philadelphia is not very happily situated as far as round-houses are concerned; they have to go a long distance to the round-house here.

Mr. Richards.—Yes, unavoidably so. It is quite a loss of time, and time is a word that counts.

Mr. McClellan.—What is the route of an engine after it leaves the coal wharf, bound south, say? What track would it take to get in advance of a train?

Mr. Richards.—I will trace an engine coming from the north on the ex-

hibit. It cuts loose from its train in the receiving yard near the hump, goes down on the engine track to the inspection pit, then, after cleaning out ashes and taking coal, it goes into the engine storage yard. It is now ready to be called to return north bound. If, it comes from the south, it takes its engine track from its stopping place near the hump and goes through practically the same maneuver and makes ready to return with a train south.

Mr. McClellan.—Can you sort out the engines in the storage yard for their particular runs or are they supposed to go out in the same order in which they came in?

Mr. Richards.—Each track in the storage yard holds about four engines; they are made short, so that any particular engine may be readily picked out. They are not intended to go out in precisely the same order in which they arrive.

Mr. Mills.—What is the classification based on—the destination of the car or the character of the freight?

Mr. Richards.—The destination of the car. For instance, we will take cars coming from the west into the Harrisburg yard. When it arrives at Harrisburg a train may be divided and some cars sent to the Cumberland Valley Railroad, to the Northern Central Railroad, to the Philadelphia and Reading Railway, to Lancaster, to Philadelphia, or through to New York—any of these different routes—and are classified accordingly.

The President.—Is that a transfer station shown on the plan?

Mr. Richards.—Yes, sir; that is a station operation for transfer of freight in cars that are to break bulk—*i. e.*, the material has to be taken out of one car, classified and put in another.

Mr. Wilson.—How long has that yard lay-out been in operation?

Mr. Richards.—It is not yet in operation; they are now constructing it.

Mr. Ballinger.—In going from Pittsburg to Philadelphia, for instance, how many such yards will a freight train ordinarily pass through?

Mr. Richards.—Large yards of this kind on our main line are located about 100 miles apart. Pittsburg and the Pittsburg division is almost a big yard of itself; coming east the next yard system is at Altoona (117 miles), and from there to the Harrisburg yard is 132 miles, and from Harrisburg to Philadelphia is 105 miles, so the large yards to which you refer are about 100 miles apart.

Mr. Ballinger.—What is the advantage, as shown on this plan, of running some of the tracks around the yard for special freight? Why not parallel to the passenger tracks?

Mr. Richards.—The special or fast freight running north, unless they had separate tracks, would interfere at the hump with the slower freight going through the classification yard. They would, furthermore, retard their time, so we give them separate tracks—simply enough to exchange engines and continue. They are nearly on passenger schedule and should stop and go about like a passenger train.

Mr. Hohn.—Would it not be just as well to run them parallel?

Mr. Richards.—It did not suit so well as having the passenger on one side and the freight on the other side. It was considered better to keep the freight tracks together, and away from the passenger tracks. It could have been done, but would not be quite so good an operation—the freight comes in better on that side.

Mr. Mills.—Is the freight handled on special tracks?

Mr. Richards.—No, the freight runs on the same tracks as the passenger. When they get north of Washington, however, they have for part of the distance special tracks. In a four-track railroad we run the freight trains on the middle and the passengers trains on the outside tracks.

Mr. Mills.—Where a full train goes between two principal cities, like Philadelphia and Pittsburg, is it necessary to run it through those yards?

Mr. Richards.—If a full train is made up from one city to another, it runs through such tracks as are shown on the outside of this yard plan, stopping only to exchange engines. We would like to see it so, as the more classification, the more delay and the more expense. The more full trains we can make up, the more we can get through, but, unfortunately, there is a great amount of classification. This is one of the troubles that railroad operators have to contend with.

Mr. Nichols.—In connection with the classification done at Altoona it occurred to me that very little of the cars classified there would require to be rehandled at Harrisburg.

Mr. Richards.—As I stated, we try to get as many through Harrisburg as we can without classification, but there are so many forks there it is quite a hard matter to get them through.

REGULATING VALVE.

J. W. LEDOUX.

Read February 18, 1905.

In waterworks' practice with gravity supplies there are many cases in which it is desirable to control the flow of water through a pipe from an upper source to a reservoir at a lower level. Suppose, for instance, a town gets its water-supply by gravity from a lake or stream situated 10 miles distant and 500 feet higher than the streets. A convenient pressure on the town would be, say, 100 pounds per square inch, but the lake pressure would be over 200 pounds per square inch, which is too much for satisfactory service. Pipes to stand this pressure would be too costly, and, besides, ordinary plumbing fixtures and fire hose would hardly stand it. To overcome the difficulty a distributing reservoir is built as near the town as possible, and at an elevation 200 feet higher. If there is a surplus of water and a means for the disposal of waste water from the distributing reservoir, it can be allowed to overflow, but usually good water at a high elevation is scarce, and often it is inconvenient to take care of the overflow. For unimportant cases, and in warm weather, a float suitably attached to a balanced or butterfly valve can be arranged to throttle or shut off the supply main when the reservoir is filled to the desired height; or, in more important cases, there can be stationed at the distributing reservoir a man who regulates the supply by an ordinary gate valve; but for various reasons these are objectionable. There are on the market automatic regulating valves operated by piston or diaphragm with spring or weight, but these are not very sensitive, and permit of a variation of water level from two to ten feet.

The apparatus herein shown is fully as sensitive and has all the advantages of a float type of regulating valve, and is at the same time free from its objections. In Fig. 1, F is a hydraulic valve on the supply main, B is a closed cylindric mercury reservoir, and C an open cylindric mercury float reservoir with a loose removable cover, K. The hydraulic valve F, is operated by hydraulic cylinder E. Water flows in the direction of the arrow into areservoir or standpipe until it is full, or the elevation of water in it is at the desired height. The pressure due to this height acts on the mercury reservoir B through the pipe Q;

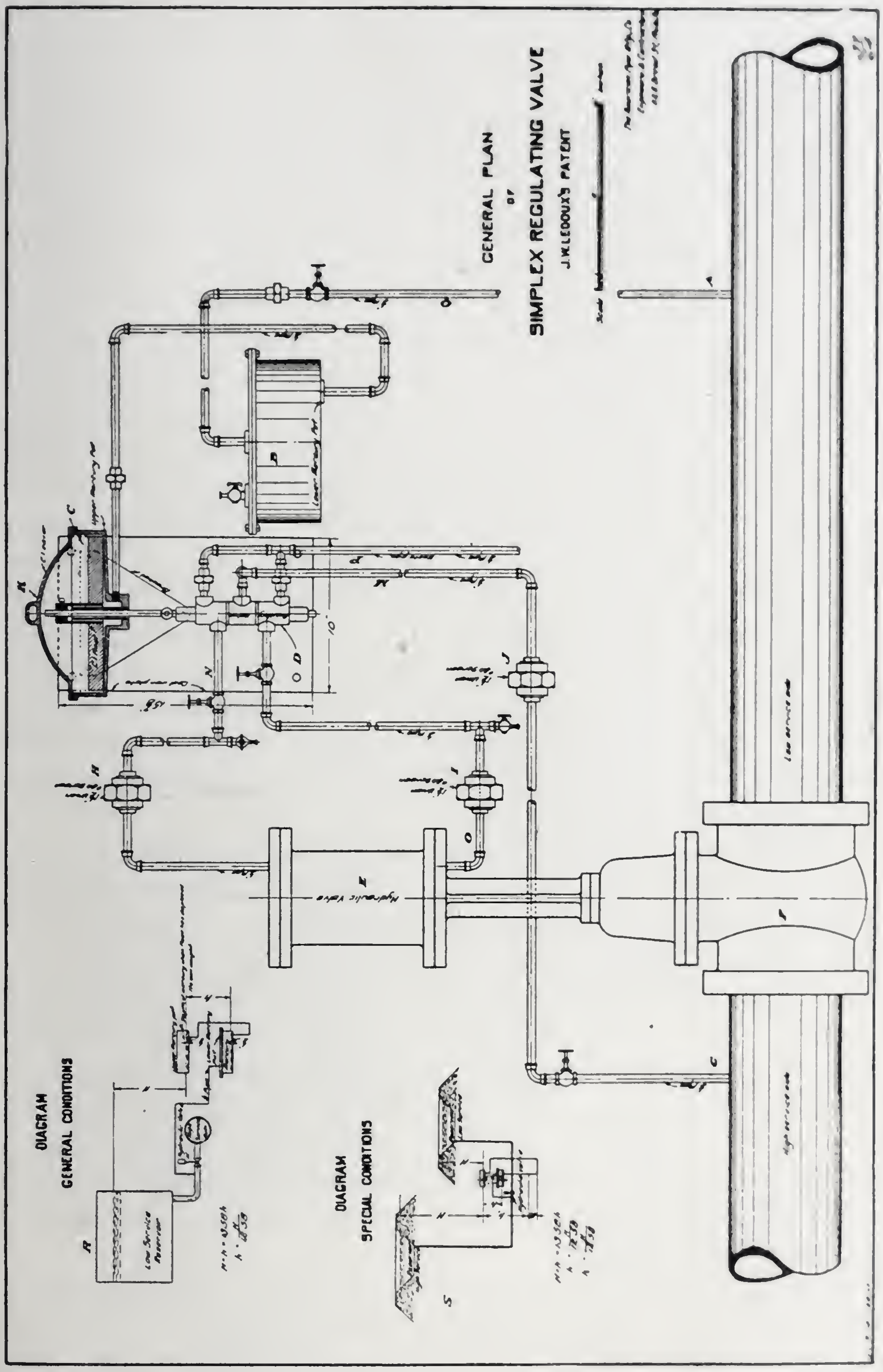

GENERAL PLAN
OF
SIMPLEX REGULATING VALVE
J.W. LEDOUX'S PATENT
DIAGRAM
GENERAL CONDITIONS
DIAGRAM
SPECIAL CONDITIONS

FIG. 1.

the mercury passes up through pipe L into the float chamber C, raising the float and operating the auxiliary five-way valve D, so as to permit water to pass through the pipes M and N into the upper portion of the hydraulic cylinder E; and at the same time the bottom of the hydraulic cylinder drains through the pipe O back through the auxiliary valve D, and out of the waste-pipe P, which in many cases may be connected with the low-service side of the valve F. This operation closes valve F. When the reservoir lowers a few inches the float in chamber C will fall, and the auxiliary valve D will operate so as to permit water to pass through the pipe M and through the auxiliary valve and the pipe O, to the bottom of the hydraulic cylinder E, and at the same time drain the top of the cylinder through the pipe N, through the auxiliary valve, D, and through the waste-pipe P, thus opening valve F. At points H, I, and J are placed couplings containing metal screens which prevent dirt from getting into the auxiliary valve.

In some cases this apparatus is operated by having the pipe Q connected on the opposite side of the hydraulic valve F. In this manner water will flow into the reservoir or standpipe until it is full, when the valve F will close as before. It will open just as soon as the pressure on the high-service side falls to a point equal to what it would be if the valve F were open and the reservoir were drawn down a few inches. This method of operation is often most convenient and is particularly useful where there is a large consumption on the high-service side of the hydraulic valve.

Theoretically, it would be desirable to have the hydraulic valve of the balanced type, in which case the hydraulic cylinder E would be very much smaller. For ordinary cases we usually specify the hydraulic cylinder 2 inches larger in diameter than that of the valve.

It is evident that the hydraulic valve F need not be the full size of the main; in fact, it is an advantage to have it smaller. It could be as small as one-third the diameter, and connected to the main pipe with reducers or otherwise. By means of the diagrams the apparatus can be located to suit the conditions and elevations existing in any particular case. It will be seen that the auxiliary apparatus is mounted on a plate, and the mercury vessel B can rest on a suitable support fixed at the required height.

If the main is very long, say 10, miles or more, the question of water hammer would have to be considered when regulating the speed at which the hydraulic valve closes. Rather than throttle too much the small pipe M, a spring relief valve, generally of 2-inch size, is placed

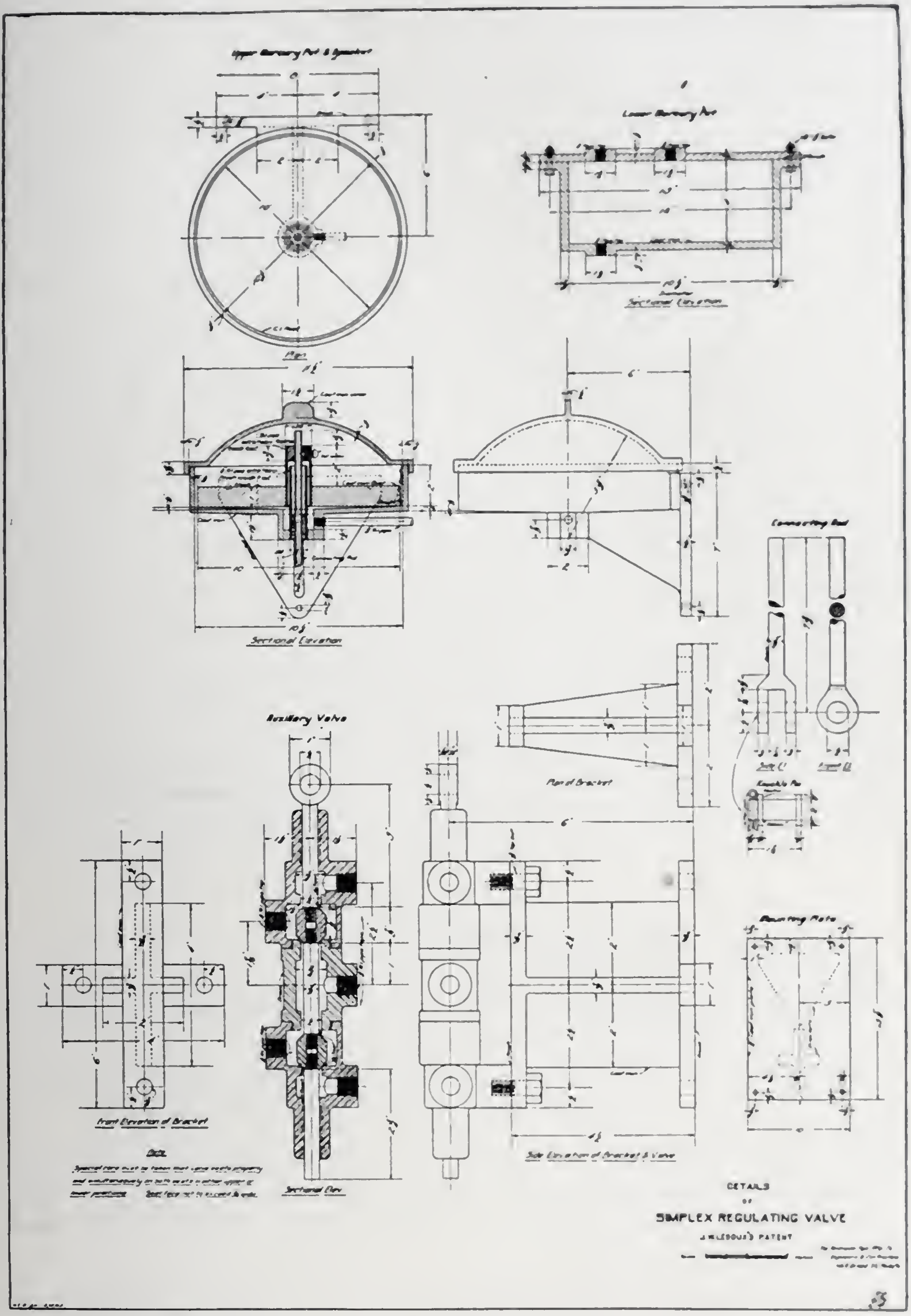

Plan
Sectional Elevation
Auxiliary Valve
Plan of Bracket
Front Elevation of Bracket
Sectional Elev.
Side Elevation of Bracket & Valve
Mounting Plate
Connecting Rod
DETAILS
OF
SIMPLEX REGULATING VALVE
J. W. LEDOUX'S PATENT

FIG. 2.

on a by-pass around the hydraulic valve F. This relief valve is so specified that it opens when the pressure is 10 pounds greater than that due to the hydrostatic pressure from the upper reservoir; and as this relief valve discharges into the distributing reservoir, there is no waste of water. In general, the relief valve is not required, especially where the hydraulic valve is made one-half or one-third the diameter of the main, because the closing of the valve is at a uniform speed, and not in the same intermittent manner as a hand-operated valve would be closed. Where the valve is of full size, the velocity in the main does not decrease materially until the valve is almost closed, and therefore the water hammer due to this retardation of velocity would be much greater than if the hydraulic valve is made small, in which case the velocity in the main begins to decrease as soon as the valve begins to close.

It is evident that the regulating apparatus and auxiliary valve can be placed at any required distance from the hydraulic valve F. Usually we place the apparatus in a gate chamber or basement of a gate house.

We have had this apparatus in regular operation on many of our plants, and it operates with absolute certainty. By its use the level of water in the reservoir can be controlled to within from one to three inches from the mean level. In one case that we have watched closely the valve continued to act for two years without a single failure; and we know of no case where the apparatus has failed to give satisfaction.

DISCUSSION.

Mr. Nichols.—Where does the waste water go?

Mr. Ledoux.—Into the low-pressure side usually, and if the pressures are too nearly alike, it is allowed to waste. The waste does not amount to much —probably not to exceed 25 to 50 gallons a day.

Mr. Nichols.—I do not get the exact object of balancing the column of water. Do you put that at a certain distance below the required level in your reservoir always?

Mr. Ledoux.—No; not necessarily. It can be placed at any desired location. The distance between the two mercury reservoirs must be right [indicating].

Mr. Nichols.—Well, isn't that governed somewhat by the relative height of location B to your water?

Mr. Ledoux.—The vertical distance between the mercury reservoirs is dependent on the height of the reservoir where water-level is to be regulated. The formulæ are given on the drawing, 13.6 being the specific gravity of mercury.

Mr. Nichols.—Then how high do you place the float above B?

Mr. Ledoux.—This is determined by the formula. Suppose the upper mer-

cury pot is located 10 feet below the reservoir. Then "H" would be 10 feet, and "h," the distance between pots B and C, or, rather, the surface of mercury in pots B and C, would be $10 \div 12.58 = 0.79$ foot, or 9.6 inches. If the distance were 12.58, the height between pots would be one foot.

Mr. Quimby.—Have you ever found the pressure interfered with by air collecting in the pipes? That would affect the pressure on the surface of the mercury, consequently the flotation of the valve.

Mr. Ledoux.—We have looked for that trouble too, but we have never found it. I do not think air could collect there to amount to anything. In some plants we have provided for that very carefully.

A Member.—Have you tried the method of filling a waste bucket to operate your hydraulic valve?

Mr. Ledoux.—Yes, sir, we have tried that, but the trouble is the small "waste" opening soon clogs up, and the apparatus fails to work.

Mr. Quimby.—Will a reducing steam valve operate successfully with water?

Mr. Ledoux.—I do not know, I am not familiar with any types of regulator valves that can be safely used on water-supply mains. They are in use, but I am adverse to them, because if they are on a long main and operate very sensitively, they shut off the main too quickly and cause serious water hammer; and if they operate slowly, it allows the high pressure to accumulate dangerously on the low-pressure side, where you do not want it. This valve works very slowly; you can see, the pipe connections are small, and the supply can be further throttled, if necessary. At Chestnut Hill we have two of these regulating valves in use, and have provided a relief valve on each. At Bryn Mawr we have one, also at Devon and Conshohocken, and in fact we have them all over the system where we have low-service reservoirs.

Mr. Nichols.—Is that a typical method of getting the water into the cylinder—through the flanges?

Mr. Ledoux.—I am not sure whether that is the best method or not. I should judge it were immaterial.

COMMUNICATED DISCUSSION.

J. D. Vogleson.—The author's statement that in *unimportant cases,* in warm weather, a balanced or butterfly valve suitably attached to a float can be used to control the flow from a supply main to a reservoir, and that in *important cases* an ordinary gate valve can be operated by an attendant, "but for various reasons these are objectionable," may be misleading, since the reasons are not given. That balanced valves operated by floats are not wholly objectionable but are in some cases well adapted for the purpose of regulating elevations of water surfaces is illustrated by a number of such valves now operating at the filter stations in this city. The design, which is not complex, is shown in the accompanying cut. (Fig. 3.)

The walking beam is supported on a platform suspended from the roof of the filters, and connects the stems of the float and the balanced valve. The float is adjustable on its stem, and by means of the walking beam transmits to the valve stem the motion caused by the changing elevation of the water surface, and thus

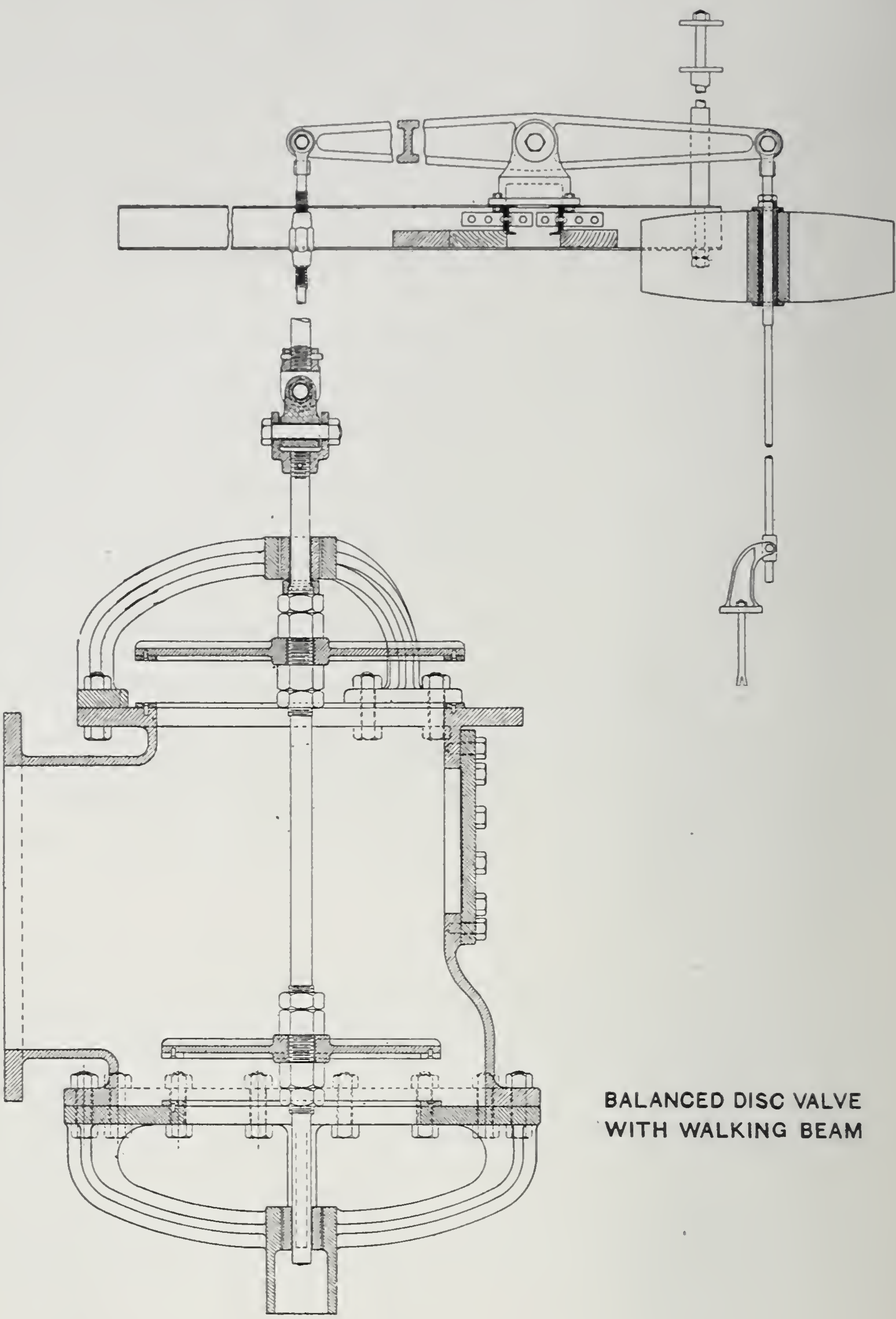


Fig. 3.

controls the flow from the supply main. Since the valves are within the filters, which are covered, it does not matter whether the weather is warm or cold.

It was reported to the writer that the valves were useless. Experiments were, however, made, and in the cases tried it appeared that the difficulty was in all probability due to the size of the floats, and indications were that they lacked both weight and buoyancy. Changes were made along the lines indicated, and the valves on which adjustments were necessary are now working satisfactorily. In one case, where the supply comes from a pumping main, the elevation is now being controlled to within $\frac{1}{4}$ of an inch; in another, where the supply is from a gravity source, the variation is $\frac{1}{8}$ of an inch; if the variation were one inch, it would still be satisfactory, and in the cases cited the control of flow by means of balanced disc valves operated by floats is all that could be desired.

Mr. Ledoux.—Referring to Mr. Vogleson's points in their order—it must be remembered that the regulating apparatus described by me was considered in its application to distributing reservoirs and standpipes, which in nearly all cases are not covered, and, therefore, would freeze in the winter. Manifestly, a float for these cases would be very troublesome. Besides that, suppose it were necessary to control the level of a standpipe 100 feet high, it will at once be seen that the rods and mechanism necessary to connect with the float would be very objectionable. Then, again, balanced valves of large size are special in their construction, and there is no regular type on the market that is all that could be desired. Some one has said that every engineer of prominence during his experience has designed at least one balanced valve and one rotary engine and afterward discarded them both. I think this is rather an unjust statement in respect to the balanced valve.

We know very well that the float plan works satisfactorily in some special cases. At Greentree, Pa., we have a small covered regulating reservoir 40 feet in diameter put in seven years ago. The supply-pipe enters the top. At the end of supply-pipe is a butterfly valve with side stem, to which is attached a lever 5 feet long having a 16-inch float at its end. This regulates the level of water very nicely to within a foot, but on account of the high pressure in the supply main (40 pounds per square inch), it will be seen that it would be difficult to get a very fine regulation unless the float were extremely large, on account of the friction in the stuffing-boxes of the valve.

ABSTRACT OF MINUTES OF THE CLUB.

Regular Meeting, January 7, 1905.—President Carl Hering in the chair. Seventy-five members and visitors present.

Mr. F. H. Von Keller presented a paper on "The Principles and Applications of Mercury Vapor Apparatus."

Annual Meeting, January 21, 1905.—President Carl Hering in the chair. One hundred and eight members and visitors present.

The Treasurer reported the names of ten active members, one junior member, and one associate member who had been dropped from the rolls because of non-payment of dues.

The annual reports of the Board of Directors and the Treasurer were accepted as printed.

The retiring President, Mr. Carl Hering, presented the annual address, in which he analyzed the progress of the Club since its foundation, and made recommendations for the future.

The Tellers reported the election of H. Watson Affleck, Arthur L. Reeder, and Charles F. Schaeffer to active membership, and W. H. Butler, H. D. Fisher, J. Scott Fowler, and Charles W. Lummis to junior membership.

The Tellers reported the election of the following officers for 1905: President, Silas G. Comfort; Vice-President, Joseph B. King; Secretary, Walter Loring Webb; Treasurer, Geo. T. Gwilliam; Directors, W. P. Dallett, John T. Loomis, and Henry H. Quimby.

Regular Meeting, February 4, 1905.—President Silas G. Comfort in the chair. Owing to the very large attendance, the meeting was held in Witherspoon Hall. Three hundred and three members and visitors present.

Mr. John W. Hill (visitor) read a paper entitled "Examination of the Torresdale Conduit."

Regular Meeting, February 18, 1905.—President Silas G. Comfort in the chair. Ninety-two members and visitors present.

The Secretary announced the death of Mr. George Holmes Perkins, active member, on February 2.

Mr. Joseph T. Richards read a paper on "The Design and Operation of a Modern Freight Yard."

Mr. J. W. Ledoux read a paper entitled "A Regulating Valve."

Business Meeting, March 4, 1905.—President Silas G. Comfort in the chair. Eighty-six members and visitors present.

The Tellers announced the election of Moriz Bernstein, Edwin M. Evans, Herman A. Jensenius, Frederick N. Morton, H. M. Platt, and Marshall R. Pugh

to active membership, and Francis H. Gilpin, W. A. McIntyre, Herbert S. Murphy, John Reilly, Jr., Irving B. Thomas, and Howard L. Yearsley to junior membership.

Mr. Robert G. Dieck read a paper entitled the "Engineering Development of Manila under American Dominion."

ABSTRACT OF MINUTES OF THE BOARD OF DIRECTORS.

Special Meeting, January 7, 1905.—Present: President Carl Hering, Vice-Presidents Foster and McBride, Directors Leiper, Loomis, Davis, Devereux, Easby, the Secretary, and the Treasurer.

The report of the Executive Committee was accepted for presentation to the Club.

The annual report of the Treasurer was accepted and ordered printed.

The Information Committee was authorized to secure a hall, with seating capacity for 250, for Mr. Hill's presentation of his paper on the Torresdale conduit; the House Committee to arrange for the luncheon.

Regular Meeting, January 21, 1905.—Present: President Carl Hering, Vice-Presidents Foster and McBride, Directors Leiper, Loomis, Davis, Devereux, Easby, the Treasurer, and the Secretary.

The Treasurer's report, dated January 3, 1905, showed:

Balance, November 30, 1904,		$933.31
December receipts,		1302.11
		$2235.42
December disbursements,		817.90
Balance, December 31, 1904,		$1417.52
On hand and in Girard Trust Co.,	$839.09	
In West End Trust Co.,	578.43	$1417.52

The Membership Committee reported that the following members had been transferred to the active list: Wm. H. Baker, Charles Day, H. E. Ehlers, Owen B. Evans, W. H. Harman, A. P. Hume, Wm. Jordan, Jr., Wallace R. Lee, Harold T. Moore, A. B. Morrison, Jr., Thorsten Y. Olsen, Charles G. Pfeiffer, Marion de K. Smith, Jr., and Samuel P. Yeo.

On motion, the following resignations were accepted: Victor Angerer, T. Norris Box, E. Chamberlain, R. D. Coombs, Jr., D. S. Cresswell, A. L. Eltonhead, E. H. Fairbanks, J. W. Henszey, C. H. Machen, J. W. Tierney and G. I Vincent.

The following recommendations to the new Board of Directors were adopted:

"That the house furniture, fixings, and library be reappraised.

"That, whereas, at times the telephone privileges of the Club are abused in

the matter of out-of-town calls, some attention be given to the amounts unpaid on these calls.

"That a fireproof safe be purchased for the records and account books of the Club.

"That the proper committee look into the value of the bond now held by the Club to ascertain if the bond could be sold and the money reinvested to better advantage; that at the same time the question be taken up as to the investment of the $500 of the cash balance.

"That the Advertising Committee be continued.

"That a complete card index of the 'Proceedings' of the Club be made, and that it be printed and distributed to the members.

"That the charges for copies of the 'Proceedings' be fixed as follows: 50 cents per copy to outsiders and 25 cents per copy to members and newsdealers, provided that the number of copies of any number of the 'Proceedings' is not less than 25, in which event enough of the 25 copies are to be set aside to complete the full sets of 'Proceedings' then on hand, and the balance to be disposed of to members only at the above price. The full sets of the 'Proceedings' are not to be broken into for the purpose of withdrawing single copies, but are to be sold complete. Authors may secure additional copies of 'Proceedings' in which their papers appear at cost, if they are ordered before going to press. Authors may secure reprints at cost, as at present."

Organization Meeting, January 28, 1905.—Present: President Silas G. Comfort, Vice-Presidents McBride and King, Directors Easby, Davis, Loomis, Dallett, Quimby, and the Secretary.

The President announced the following Committees: *Finance*, W. P. Dallett, G. C. Davis, Joseph B. King; *Membership*, Wm. Easby, Jr., Geo. C. Davis, W. P. Dallett; *Publication*, Henry H. Quimby, Wm. Easby, Jr., Thos. C. McBride; *Information*, Thos. C. McBride, Wm. Easby, Jr., Joseph B. King; *Library*, Washington Devereux, Joseph B. King, Henry H. Quimby; *House*, John T. Loomis, Washington Devereux, Geo. C. Davis; *Auditors*, H. W. Spangler, R. L. Humphrey, Francis Head; *Tellers*, W. E. Bradley, I. W. Hubbard, H. P. Cochrane; *Alternate Tellers*, Emile G. Perrot, Alan Corson, F. E. Dodge.

Regular Meeting, February 18, 1905.—Present: President Silas G. Comfort, Vice-President McBride, Directors Easby, Dallett, Quimby, Davis, Loomis, Devereux, the Secretary, and the Treasurer.

The Treasurer's report, dated February 14, 1905, showed:

Balance, January 1, 1905,		$1417.52
January receipts,		1942.35
		$3359.87
January disbursements,		366.33
		$2993.54
On hand and in Girard Trust Co.	$2415.11	
In West End Trust Co.,	578.43	$2993.54

The Secretary reported the death of George Holmes Perkins, at Island Heights, February 2.

The Secretary's selection of Clerk at $35 a month was approved.

It was moved that the lease for the Club House be executed in accordance with a letter of the Girard Trust Company, if it meets with the approval of the House Committee and the President.

Moved and carried that the Advertising Committee be continued; the personnel to be: The Treasurer, the Secretary, and the Chairman of the Publication Committee.

The resignations of A. B. Morrison, Jr., and S. Godfrey Griffith were accepted.

By resolution, the Treasurer's salary was increased from $60 to $120 per year, and that of the Secretary was increased from $240 to $360 per year, dating from February 1.

ADDITIONS TO THE GENERAL LIBRARY.

FROM STATE BOARD OF HEALTH, MASS.

Thirty-fifth Annual Report of the Board.

FROM EDWARD ORTON, STATE GEOLOGIST.

Geological Survey of Ohio, fourth series, Bulletin 2.

FROM UNITED STATES COAST AND GEODETIC SURVEY.

Report of the Superintendent for 1904.

FROM CHARLES D. WALCOTT, DIRECTOR.

Water Resources of the Philadelphia District.

FROM MUNICIPAL BOARD, MANILA, P. I.

Report of the Municipal Board for 1904.

FROM C. E. SHERMAN, INSPECTOR.

Preliminary Report of the Ohio Co-operative Topographic Survey.

THE ENGINEERS' CLUB OF PHILADELPHIA

1122 Girard Street

OFFICERS FOR 1905

President

SILAS G. COMFORT

Vice-Presidents

Term Expires January, 1906
THOS. C. McBRIDE

Term Expires January, 1907
JOSEPH B. KING

Directors

Term Expires January, 1906

WM. EASBY, JR.
GEORGE C. DAVIS
WASHINGTON DEVEREUX

Term Expires January, 1907

W. P. DALLETT
HENRY H. QUIMBY
JOHN T. LOOMIS

Secretary
WALTER LORING WEBB

Treasurer
GEORGE T. GWILLIAM

Clerk
MARJORY LAMBE

STANDING COMMITTEES OF BOARD OF DIRECTORS

Finance—W. P. DALLETT, GEORGE C. DAVIS, JOSEPH B. KING.
Membership—WM. EASBY, JR., GEORGE C. DAVIS, W. P. DALLETT.
Publication—HENRY H. QUIMBY, WM. EASBY, JR., THOS. C. McBRIDE.
Information—THOS. C. McBRIDE, WM. EASBY, JR., JOSEPH B. KING.
Library—WASHINGTON DEVEREUX, JOSEPH B. KING, HENRY H. QUIMBY.
House—JOHN T. LOOMIS, WASHINGTON DEVEREUX, GEORGE C. DAVIS.

MEETINGS

Annual Meeting—3d Saturday of January, at 8 P.M.

Stated Meetings—1st and 3d Saturdays of each month, at 8 P.M., except between the fourteenth days of June and September.

Business Meetings—When required by the Constitution or By-Laws, when ordered by the President or the Board of Directors, or on the written request of five Active Members of the Club.

The Board of Directors meets on the 3d Saturday of each month, except July and August.

PROCEEDINGS

OF

THE ENGINEERS' CLUB

OF PHILADELPHIA.

ORGANIZED DECEMBER 17, 1877. INCORPORATED JUNE 9, 1892.

Vol. XXII. JULY, 1905. No. 3

PAPER NO. 1005.

THE ENGINEERING DEVELOPMENT OF MANILA UNDER AMERICAN DOMINION.

ROBERT G. DIECK.

Read March 4, 1905.

THE city of Manila, founded on the Island of Luzon by Legaspi in 1571, lies at the delta of the Pasig River on the northeastern shore of Manila Bay and embraces a territory of about twelve square miles. For political purposes the city is divided into thirteen districts whose limits are defined, for the most part, by the numerous esteros or mouths of the river. Near the mouth of the river the soil is a sandy deposit with an admixture of clay overlying a bed of river gravel of considerable but varying depth, which under the frequent severe earthquake shocks assumes a very dangerous character. Proceeding inland, the soil becomes less sandy and a greater quantity of clay is found. In the northern and northeastern sections, where rolling land is encountered, the sand and clay are combined in a soft stone known as "dhobe" or the "washerman's" stone, which is extensively used for building purposes, but is extremely brittle and deteriorates rapidly. The average elevation of 85 per cent. of the area of the city is not greater than 12.00 meters, City Datum, the datum plane of mean low water as determined by the United States Coast and Geodetic Survey being assumed at 10.00 meters. In this area the land surface varies in elevation from 11.25 to 12.75 meters, and affords little natural drainage.

From the time of the founding to the incorporation as a municipality by the United States Philippine Commission in August, 1901, the development of the city was extremely slow. The roadways were rough and unclean, buildings were erected on no definite street lines, and little attention was paid to the health or comfort of the inhabitants. Large areas set aside for public purposes (mostly of a military character) were utterly neglected and acknowledged as convenient dumping-grounds for refuse. There was a horse tram in operation, run entirely for the inconvenience of the citizens at infrequent intervals, which was endured until the past year. A steam tram connects the city with the town of Malabon to the northwest. In the year immediately preceding the American occupation, under the able direction of Don Carlos de las Heras, a Spanish engineer officer, who occupied the office of City Engineer, a wise policy of municipal improvement was inaugurated, but the outbreak of the Philippine insurrection and the arrival of the American forces prevented the accomplishment of his well-laid plans. He attacked the subjects of street drainage, house drainage, and the improvement of the esteros, in a masterly manner. He designed and built to the water-line the piers for a bridge across the Pasig River which were later used by the Americans in the construction of a Pratt truss bridge, and his scheme for the revision of the city lines has been adopted in part by the American engineers. It is to his skill and energy that Americans owe most of their aid from Spanish sources.

The flatness and general low elevation of the city require the construction of a separate system of sewerage. Outfalls for stormwater sewers are easy to find on account of the numerous esteros, which limit the length of sewer runs to the maximum of 1000 meters. The tides at Manila are produced by two waves, one the direct tidal disturbance from the Pacific Ocean, proceeding from the south through the San Bernardino Straits, and the other a retarded disturbance from around the north end of Luzon. Uniting at Manila, a very complex tidal movement is produced, giving either one or two high tides per day. A careful study of the tidal curves has established the fact that ordinary low tide occurs at elevation 10.30 C. D., and it has therefore been determined to construct no sewers below that elevation, in order that fouling may be prevented. The heavy hauling on the streets requires that a reasonable depth over the sewers should be maintained, and the minimum of 60 centimeters has been fixed. It is seen, therefore, that between elevation 10.30 and 11.40, on the average, most sewers

must be constructed. Rainfalls of intensities of 3 inches per hour occur on the average once each year, but in the sewers already designed an intensity of 2 inches per hour with 75 per cent. run-off has been used. Under maximum rainfall, therefore, the sewers will run under pressure, and temporary flooding of the streets may ensue. This concession has been made solely on the score of economy, but no evil effects have been noted in the case of sewers already constructed. The high cost of filling material has forced the condition of flat gradients, but the minimum allowable curb grade has been fixed at 1 in 500 and the minimum curb elevation at 11.50 C. D. So far, about 50 per cent. of the street grades have been established and sewers designed, and within the present year the designs will be completed. The work of sewer construction has commenced, but the lack of funds has delayed the completion of the work.

The house drainage of the city has also been considered, and a comprehensive scheme prepared. The estimates are based upon the installation of a pumping system with a discharge, after several lifts, into Manila Bay about 1000 meters offshore. The outfall will lie at the foot of Calle Azcarrage, in the District of Tondo, and all sewage will be discharged at that point. The estimated cost of construction is $2,000,000. Actual operations on the installation of this system cannot be commenced until funds have been secured by a bond issue.

The water-supply is at present obtained from the Mariquina River at a point about eight miles from the center of the city, where a pumping station with four 2,000,000-gallon pumps (of which two were assembled by Americans) is established. The water is lifted about 80 feet into a conduit, for the most part in tunnel, conducted to an underground reservoir four miles distant, and from that point distributed to the city. This system, placed in operation in 1882, is now inadequate for the public needs. The per capita consumption has increased during American occupation from 25 gallons to 35 gallons per day, as a result of the extensive street sprinkling, the development of the city parks, and the general introduction of sanitary fixtures. The danger from shortage of water during the summer months has been met by the strict enforcement of the law requiring metered connections, and by a rigid inspection of private services. A new source of supply will be sought in the upper reaches of the Mariquina River at a point about fourteen miles northeast of the city, in a direct line from the present reservoir, where a sufficient storage to insure a steady supply of twenty million gallons per day may be secured. The dis-

tributing reservoir will be increased in capacity about eight times by the removal of the roof and the raising of the water-level about seven meters. The water-pressure in the city will be thereby increased from its present maximum of twenty-five pounds to a maximum of forty pounds, and the supply made more steady. The estimated cost of the work, excluding the necessary adjustment of the distributing system, is $1,500,000. Since the American occupation the distributing system has been thoroughly overhauled, 225 new post hydrants have been set, and the Office of Water-Supply equipped with modern American tools.

The water is far from good in quality and was one of the means of spreading the recent epidemic of Asiatic cholera. The amœbæ of dysentery are found in large numbers in the water, as are the germs of typhoid. Efforts are now being made to remove these amœbæ and germs by the addition of copper sulphate as a germicide, in the proportion of one part sulphate to 4,000,000 parts water. The experiments thus far conducted have not been productive of direct results, but it is expected that within a few months the complete removal of these organisms will be effected.

The street area of the city is approximately 1,500,000 square meters in extent, of which about 95 per cent. is laid in macadam of a very unsatisfactory nature. The difficulties lie in the poor foundations on account of the saturated subsoil, and in the character of the local stone, which has little binding qualities and wears unevenly. Some success has been had with gravel, but only in the less traveled streets. A general thickening of the wearing surface has, however, decreased the destructiveness of the traffic. Concrete curbing on the more important streets and regular sprinkling have aided materially in the preservation of the road surface. Improved pavements have scarcely been considered because of the high cost of materials, but within the last year the city has completed about 10,000 square meters of Australian wood block pavement, which has given satisfaction. Three new openings have been made in the city wall and one gate widened. These improvements have markedly relieved the traffic congestion of the Walled City.

During the confusion attending the American investment of the city many official records were lost, including the city plan and the original survey notes, and it was necessary to commence at once the survey of the city. Later the city plan was recovered by purchase from the person who had removed it, but the notes have never been

found. Because of the establishment of a Court of Land Registration, re-survey of the city was soon commenced, and since 1901 has been continued as opportunity has allowed. The effect of the work is quite noticeable in some districts in which the streets are being widened and straightened. New street schemes have been approved for the Districts of Santa Cruz, Sampaloc, Paco, Pandacan, Ermita, and Malete, with streets on the rectangular plan. In part the necessary field work has been completed. Lines have been established on many streets as requests for building lines have been filed. In the settlement of claims for damages for land taken in street widening the city has wisely employed committees of arbitration, which have succeeded admirably in adjusting the differences without delays. Standard street sections and subdivisions have been adopted. The following rule is observed:

For streets less than 20 M. wide, sidewalks $\frac{1}{6}$ width, roadway $\frac{2}{3}$ width.

For streets more than 20 M. wide, sidewalks $\frac{1}{5}$ width, roadway $\frac{3}{5}$ width.

The location of underground structures on new streets has been fixed, and standard locations given to hydrants, valves, inlets, poles, etc. All lines and grades for sewers, water-pipes, houses, and other structures, are given by instrument.

Under the control of the insular government the harbor facilities are being improved. The breakwater built by the Spanish government has been extended and strengthened. An area of about one-half of one square mile has been reclaimed by the construction of a bulkhead and the filling of the space in the rear with dredgings from the bay. In this area storehouses will be constructed. It is intended to provide entrance to the bay for vessels of 30-foot draft. Considerable danger arises from the strong southwest winds which blow during the typhoon season, and protection against these is to be afforded by the construction of a breakwater and harbor with a wide entrance to offer protection to sailing vessels. Inter-island steamers of 14 feet draft can now enter the Pasig River to the Bridge of Spain, and launches of 6 feet draft can pass to the Laguna de Bay, a large fresh-water lake some fifteen miles from the river's mouth. A portion of the city wall along the river has been removed and a wall is under construction for the accommodation of the inter-island shipping.

The transportation facilities of the city have developed rapidly. The Pratt truss bridge over the Pasig and the new openings in the city wall have been mentioned. The firm of J. G. White & Co. of

New York has almost completed an overhead-trolley tramway system with some 12 to 15 miles of track, and has announced that on March 1st the road would be thrown open to business. The streets will then be relieved of the greater portion of the vehicle traffic. The city has under contract two bridges, one a steel Pratt truss over the Pasig to replace the overtaxed Ayala bridge, and the other a steel lift bridge across the Estero de Binondo to furnish a direct outlet to the water front and Customs House. Plans are also under consideration for the construction of a modern bridge over the Pasig below the Bridge of Spain, which ancient structure is in a more or less dangerous condition and usually ordered closed during high floods.

Hauling for the city is managed by the municipal authorities. The stock consists of 350 head of animals—American and Chinese horses and mules and native ponies. The harness, wagons, and general equipment are of American manufacture and are in prime condition. Apparently the greatest success with animal transportation is attained with American mules. These animals eat less, work more, are sturdier, and resist surra, glanders, and rinderpest, better than even the native stock. The Office of Water-Supply operates a road locomotive of 15 tons dead weight, and a train of four cars of 20 tons nominal carrying capacity, for the hauling of coal and heavy materials to the pumping station. The Office of Streets employs two powerful steam launches, and 30 barges of about 25 C. M. capacity, in the delivery of road material from the city quarry in the Laguna de Bay.

The main streets are sprinkled daily (in the more important sections by sprinkling wagon, and in the lesser important by hose or sprinkling can) at least twice during the heated term from April until July, and during the remainder of the year as occasion demands. The sprinkling equipment consists of 18 four-horse wagons of a combined capacity of about 14,000 gallons. Because of the wastage of water and the destruction of road surface by hose sprinkling, combined with heavy labor cost, the territory of wagon sprinkling is being rapidly extended. Great assistance has been rendered by the new crane post hydrants, from which the tanks are rapidly and economically filled.

The park area of the city is small, but the grounds are in excellent condition. The intense heat and the long continuance of the dry season offer serious obstacles to the development of parks of large extent, and it is my belief that the park area must be confined to small breathing spots. It is the intention of the United States Philippine Commission to develop a general system of parks and boulevards,

and to that end the services of Mr. Burnham of Chicago have been sought. A well-digested scheme such as this will serve to make Manila the peer of any city in the East.

It is in its cleanness, however, that Manila stands preeminent. Under the Spanish régime there existed no scavenger department worthy the name, and the street dogs were fat and plentiful. At one time considerable inconvenience and danger attended walking on the streets in the early hours of the morning, as liquids of a doubtful nature and the remnants of the previous night's meal were liable to arrange themselves on one's clothing. The filth of generations was collected in dark corners, and privy-vaults of great size, uncleaned for years, discharged their filth into the courts and even into the highways. The soil was poisoned with these discharges and a general state of sickness followed upon excavations. The collection of garbage was practically a failure, and the parks were used as public toilets. Through the determined action of the city and the Board of Health, buildings have been cleaned, offensive vaults directed to be filled or made tight, and sanitary fixtures ordered in the larger houses and hotels. The introduction of sanitary fixtures has increased the consumption of water, but has been the means of preventing or lessening the spread of tropical diseases. Cholera is rare and the spread of bubonic plague completely checked. Beri-beri and leprosy are rare except among the natives, and the general health is fair. As before remarked, amœbic dysentery is very prevalent, but this will surely be controlled. Smallpox, formerly an annually recurring disease, is no longer a serious danger, except to those unvaccinated. A plan for the drainage of the lowlands and marshes of the city is being considered, and petroleum is being placed in the haunts of the mosquito of malaria.

Garbage is now collected every day after nightfall from tight cans, which owners are required to place in definite positions in front of their properties, and removed by cart to two crematories, one of 40 tons nominal capacity on the south side of the Pasig, and the other, —a Morse-Boulger of American make,—designed to digest 120 tons, on the north side. This latter does not operate to its maximum, due to the peculiar character of the Manila garbage, which consists for the most part of leaves, branches of trees, and the parings of fruit, with practically no dry paper or rags. Considerable difficulty attends the burning, particularly in the wet season, and the capacity of the plant is much reduced at that time. In ordinary weather from 90

to 100 tons of normal garbage can be consumed. The city is seriously considering the erection of a large plant on the south side of the river to equalize the burning and to reduce haul.

Street sweepings are carefully preserved and classified. Horse droppings are spread in the parks and ordinary sweepings used for filling. Large areas of low-lying public lands and dry water-courses have been reclaimed by filling of this kind.

Where it is not possible to discharge house wastes into water-courses or sewers, the pail conservancy system is employed. Collections of used pails with covers screwed down are made each evening after sundown, and clean pails left. The pails are hauled to a central station on the Pasig River, below the Bridge of Spain, and the contents dumped into the tanks of a steel barge through hoppers with automatic flap valves. The pails are washed at the time of dumping by a powerful spray of water in the hopper, and afterward disinfected with carbolic acid. Each day the barge steams to sea, and at a distance of about fifteen miles from shore is discharged through side doors. The administration of the Bureau of Street cleaning, transportation, and refuse disposal, is given to Mr. John C. Mehan, formerly of the same bureau in Havana, and it is the most perfect organization in the Philippine Islands.

I have but lightly touched upon the many improvements which the American Government has effected within its short existence, but there has been enough said to show that there has been no idleness. When it is considered that practically all of this work has been done since the fall of 1901, the results are truly astounding. There have been serious engineering difficulties to overcome, but it must be remembered also that there have been present the peculiar differences in language, sentiment, and customs. Besides the works of a purely engineering nature, the Government has accomplished the organization of a fire department of six companies, equipped with the latest type of ladder trucks, engines, hose wagons, harness, and life-saving apparatus, and has installed an electric police and fire-alarm system. The police department has, by excellent organization, made the notoriously bad surroundings of Manila absolutely safe. The public schools have also assisted in the work of improvement by encouraging in the natives an interest in public affairs, and the whole Filipino people have benefited by the lesson of Manila. As Americans we may be justly proud of these our first real efforts in the development of a tropical colony.

DISCUSSION.

In reply to numerous questions the following additional facts and data were contributed by Mr. Dieck:

The widths of the American streets are from ten meters upwards, but the Spanish streets vary from three or four meters to ten or twelve, the average being perhaps eight. There is on this account great difficulty in controlling fires, though they seldom occur. The minimum width of projected streets is fifteen meters. The main street is twenty-five meters. The houses do not have projecting steps; if the floor is above the surface, the steps are inside the house.

The underground reservoir was excavated from the live rock entirely by pick. The rock is soft, of course, but the achievement by hand labor was a great one. No mortar was used except in some places where slides occurred. The roof is cut into groined arches, the supporting pillars being about five meters high from floor to springing line. The floor is paved with tiles. During the siege of the city, several American shells dropped in through the roof, and the holes have been repaired with concrete.

The main water-pipe line is a 26-inch main. A severe flood caused a portion of it to move down-hill, producing a bulge in the line. This portion was raised and supported on concrete piers—one under each bell of the joints. The rainfall over Manila during this flood was 17.19 inches in thirty-six hours. At the point where the pipe was dislodged the water was about six feet deep and flowed over the pipe at a speed of about fifteen miles per hour. About 300 feet of the pipe was pushed laterally seven feet, but no water was lost and no damage was done to the pipe, which carries about 25 pounds pressure. The joints of the pipe were made with lead and were about twenty-five years old, and had during that time received only passing attention. The bells are about 4 inches deep, giving about 2½ inches of lead. Some of the joints pulled out as much as ¾ inch, but there was absolutely no leakage. The pipe was English made.

Traction engines were used to carry coal and build roads. We did a great deal of work with them, but the operation was not entirely satisfactory. The preliminary estimates were that the cost would be about 25 cents per ton mile, but I do not know the actual cost.

The old sewer shown in the views takes the drainage of about one square mile of territory. It was very close to the surface. The arch of it was laid up in mud mortar and the invert without mortar. We found twenty-seven holes in a distance of 300 feet. Most of these holes had been filled with keystones extending eight or ten inches down into the sewer. We repaired the sewer in places by spreading about five inches of concrete on the top in the reinforced parts, and where necessary we rebuilt the arch to a thickness of nine inches. The inside of the sewer and the bottom were run with cement mortar in a 1 to 4 mixture and a very neat job made.

Another Spanish sewer on the Escolta—age unknown—was giving similar trouble, and upon uncovering it the whole structure fell in. It was rebuilt of concrete in basket-handle form about 34 inches wide in clear, from invert to springing line about 24 inches, and the invert is a circular arc about three inches deep. Average tide is about three feet and the maximum tide is from four to five feet.

The houses have no cellars and many are built on stilts. The soil is sand and gravel.

The Spaniards construct their buildings altogether of native stone, but the Americans are trying to build everything more cheaply. Brick is made there, but is expensive and is not used for paving.

The views show the first street built on American lines. It has concrete curbs and the gutters are laid with China stone to facilitate the flow of water on the famous grade of 1 to 500. The native stone is expensive and not very satisfactory. The cement generally used is made in Hong Kong and is not as good as American Portland, which costs there about $2.50 per barrel.

The views show also the new building for the Government laboratories. It is a magnificent structure costing $110,000, equipped with the most modern instruments and devices for investigating all kinds of diseases.

Also one of the companies of the American Fire Department, fully equipped.

Also a new gate cut through the city wall. The American style of architecture does not accord well with the Spanish wall.

The old city of Manila is completely walled. It has an area of about one-half square mile and the wall is about two miles long. The stone is soft, and it is common to see walls where the stone has disintegrated and broken away, leaving the mortar joints projecting. Some portions of the wall are 250 years old. It is 20 feet thick at the top and 30 feet thick at the base. There are outworks and embrasures for artillery. In many places the walls have vaults under them which had been used for prisons, arsenals, and magazines.

There are a number of waterfalls within reach of the city, any one of which would be sufficient to furnish power, and the Government is thinking of developing them. The natives have made no use of them.

The islands are a timber country, but the lumber is so hard that it costs as much to saw it as it is worth. American third-class lumber there was worth, if I remember correctly, about $20 per thousand, and native lumber sawed about $60 to $100. It is very tough. I have seen a piece 4 inches square sawed with a circular saw revolving at high speed, and it actually took fifteen minutes to get through it, and the saw had to be stopped twice to cool off. This is the case with green lumber, and it seems to be always green; it is very rarely that you can get a piece of seasoned wood. Fine band saws will not go through the wood. It is very durable—I have seen sticks that have been in the ground for forty years without apparent deterioration. The woods are very dense and many will not float in water. Rafts of such must be floated with bamboos.

The population of Manila was at last count 215,000, about 55,000 of whom live on boats.

The temperature in December and January is about 65° at sunrise and 80° at noon. In April, May, and June, which are the hottest months, it is about 85° in the morning and 100° at noon. The humidity in these months is about 80 per cent. The air is quite humid at all times. The rainy season is from the middle of June to the middle of January, but principally from July to November. It does not rain all that time, but most of the rain-storms occur during that period. Other periods of the year are practically dry.

The metric system of weights and measures is in general use there. It was adopted by the American administration because all the old records were in it,

and much difficulty was found in the use of American tapes graduated in feet and inches. We found the metric system very convenient and I have learned to think in meters.

The city is lighted by electricity—both arc and incandescent—installed by the Spaniards.

The fuel mostly used is coal from Australia and Japan. Some wood is also used. Soft coal from Australia costs about $6.25 per ton. Japanese coal contains a great deal of sulphur and is undesirable for some purposes.

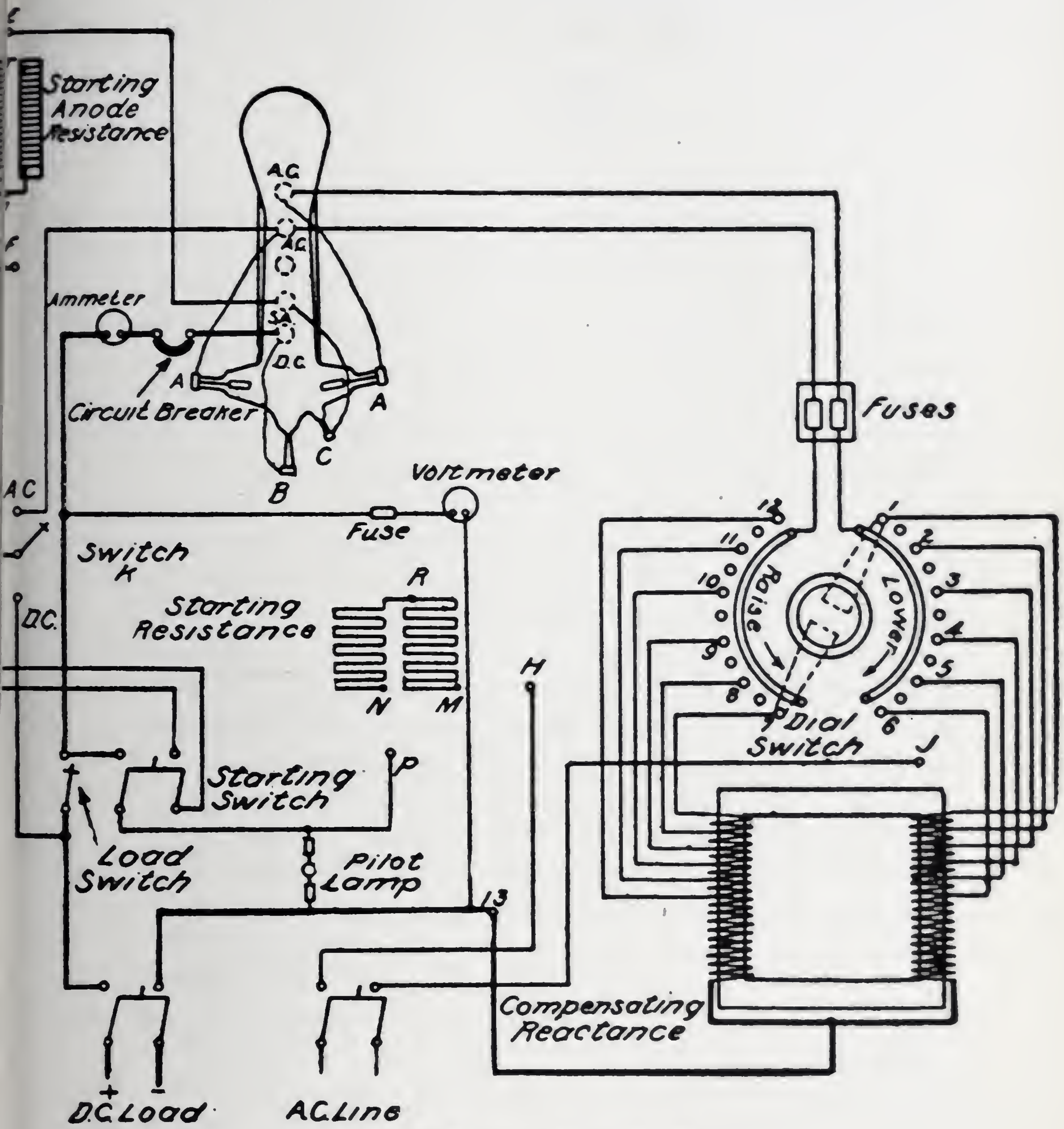
PAPER NO. 1006.

MERCURY ARC RECTIFIER.

E. P. COLES.

Read March 18, 1905.

THERE are some uses of electricity for which the direct current alone can be used, prominent among which is the charging of storage batteries, and in many cases only alternating current is available. In order to get direct current from the alternating current there are several methods which may be resorted to—either a motor-generator set, or a rotary transformer, or this mercury arc rectifier which I will show you in operation a little later. The principle of this rectifier is this: The body is a glass tube with as nearly a perfect vacuum as can be made, and there is mercury in the bottom of it. The anodes A have the alternating current attached to them; the cathode B is at the bottom, and from this proceeds the positive side of the direct current. The negative side of the direct current is derived from the middle point of a reactance C which is connected between the two terminals (anodes). The principle, roughly, on which this works is that in the vapor of mercury which is generated in this tube the alternating current can only pass in one direction, and as a consequence one alternation passes in from one direction, the other alternation from the opposite direction, and each in turn is rectified, or converted into direct current, and passes from the cathode. Anode C is merely for starting purposes, and when the rectifier is started it is slightly tipped, so as to make a mercury arc between C and B, and then it is brought back to the ordinary position, and that starts the mechanism in operation. The anodes are simply connected through platinum wire to a carbon contact, and the same way on the cathode and the starting anode. The direct current potential can be varied to suit the requirements, by changing the connections of the reactance, and this is done by a switch on the board.



Connections of Mercury Arc Rectifier.

PAPER NO. 1007.

REINFORCED CONCRETE—SOME OF ITS PRINCIPLES, WITH PRACTICAL ILLUSTRATIONS.

WALTER LORING WEBB.

Read March 18, 1905.

ECONOMICS.

THE justification of the use of reinforced concrete is usually based on some one or all of three conditions. First, under some circumstances it is actually more economical than any other rational method of construction. Secondly, there are cases where it is almost the only practicable method of construction. Thirdly, there are cases where it is simply preferable. It is not very easy to demonstrate the economy of this method except by comparative cost in individual cases, but an approach to a systematic comparison may be made as follows: A cubic foot of steel weighs 490 pounds. Assume as an average price that it can be bought and placed for 4.5 cents per pound. The steel will therefore cost $22.05 per cubic foot. On the basis that concrete may be placed for $6.00 per cubic yard, the concrete will cost 22 cents per cubic foot, which is 1 per cent. of the cost of the steel. Therefore, on this basis, if it is necessary to use as reinforcement an amount of steel whose volume is in excess of 1 per cent. of the additional concrete which would do the same work, there is no economy in the reinforcement, even though the reinforcement is justified on account of the other considerations. Assuming 500 pounds per square inch as the working compressive strength of concrete, and 16,000 pounds as the permissible stress in steel, it requires 3.125 per cent. of steel to furnish the same compressive stress as concrete. On the above basis of cost, the compression is evidently obtained much more cheaply in concrete than in steel—in fact, at less than one-third of the cost. On the other hand, even if we allow 50 pounds per square inch tension in the concrete and 16,000 pounds in the steel, it only requires 0.31 per cent. of steel to furnish the same strength as the concrete, which shows that, no matter what may be the variation in the comparative price of concrete and steel, steel always furnishes tension at a far cheaper price than concrete, on the above basis, at less than one-third of the cost. The practical meaning of this is, on

the one hand, that a beam composed wholly of concrete is usually inadvisable, since its low tensile strength makes it uneconomical, if not actually impracticable, for it may be readily shown that, beyond a comparatively short span, a concrete beam will not support its own weight. On the other hand, on account of the cheaper compressive stress furnished by concrete, an all-steel beam is not so economical as a beam in which the concrete furnishes the compressive stress and the steel furnishes the tensile stress. This statement has been very frequently verified when comparing the cost of the construction of floors designed by using steel I-beams supporting a fireproof concrete floor, and that of a concrete floor having a similar floor slab but making the beams as T-beams of reinforced concrete.

Another instance of the actual economy of this method of construction is furnished by a recent design for a retaining wall. The wall was to be 14 feet in height and the design was for a skeleton reinforced concrete construction. It has a base plate of the requisite width, so that the center of pressure of the base will be properly located. Buttresses which run back into the embankment at proper intervals are connected with the base plate, while the face of the wall between the buttresses has only such thickness as is required to withstand the bursting pressure developed between each pair of buttresses. The whole structure is reinforced with steel so as to take up all the tensile stress which may be developed in any part of the wall. The cross-section of this wall has an average value of 25.44 square feet, which is the equivalent of 25.44 cubic feet per linear foot of wall. A wall of rubble masonry was designed by well-known railroad engineers for this same location. This wall had a cross-section of 80.45 square feet. On the basis of 25 cents per cubic foot, or $6.75 per cubic yard, each linear foot of the rubble wall would cost $20.12. Of course, the unit price of the concrete wall is considerably higher, but its volume is but little over 30 per cent. of the volume of the stone wall. In this particular case an estimate for this wall at the rate of 40 cents per cubic foot as measured in place was obtained from a reliable contractor, the estimate including the steel and all other items of construction except mere excavation, which was not included in the first estimate. The concrete wall would therefore cost $10.16 per linear foot, which is practically *one-half* of that of the stone wall. Many other illustrations could be given where reinforced concrete construction is the cheapest that gives a permanent structure.

As an instance of the second class of structures, viz., those in which

reinforced concrete is almost the only practicable method of construction, the following case is given. It was required to construct a retaining wall with a height of 36 feet above the rails of a sunken track where the right-of-way was absolutely limited to a width that gave 10 feet from the right-of-way line to the clearance line for the tracks. The wall was designed to have its base 42 feet below the top. Of course, 10 feet is too small a base for a 42-foot retaining wall. The only possible solution appeared to be some provision by which the toe of the wall could extend underneath the track. Of course, such a construction in stone masonry or even in plain concrete would be an utter impossibility, since it would inevitably break at the angle at the base. A structure of concrete and steel in which the transverse stress at the lower angle of the wall is resisted by the horizontal steel bars in the base, with the very considerable pressure of the earth on the base plate behind the face wall, accomplished all that is desired. The resultant line of pressure is within the middle third of the base, while the maximum intensity of pressure on the subsoil was computed to be about 6400 pounds per square foot. As the subsoil is a very firm gravel this pressure is a perfectly safe one, but if it had been found that the soil was less reliable it would have been a comparatively simple matter to enlarge the foundation as much as necessary. Of course, the conditions of this problem were very peculiar and unusual, and it illustrates what can be done under such circumstances.

Since the above was written the "Engineering News," in its issue of March 9th, page 262, published an interesting account of a wall constructed by the Great Northern Railway Company at Seattle, Washington. The wall is over 40 feet from base to top at the highest point, varying from this maximum to nearly zero. The economy of the design in comparison with a wall in plain concrete was computed. There was shown to be a saving of 20.4 per cent. for a wall 10 feet high and of 45 per cent. for a wall 40 feet high. But in this case there was no question of limitation of the base of the footing behind the face of the wall, and therefore no necessity of extending the toe of the wall under the tracks.

The third class of structures, viz., those in which reinforced concrete is simply preferable, may be illustrated by the very simple case of fireproof floors. One of the compensations of the Baltimore fire was its demonstration of the fact that a concrete floor when properly made approaches the ideal by being more nearly absolutely fireproof

than any other flooring material. It has been frequently stated that since concrete is formed by the crystallization of a compound containing water, it only requires heat to drive off the water and render the whole structure worthless from a structural standpoint. In one sense this is true, provided the heat is sufficient; but the Baltimore fire proved that even with the very excessive degree of heat which was developed during that fire, the effect of such heat on a concrete floor was merely to calcine the lower layer of concrete to a depth varying from ½ inch to 1 inch. After such calcination occurred, this layer of heat-resisting material proved to be such a thorough protection that the concrete above it was uninjured, and considering that the concrete that lies above the axis of the reinforcement is the only portion which is considered in calculating the strength, and also considering that an inch or two of concrete is always placed below the steel reinforcement, even the destruction of an inch of concrete on the lower side of a concrete slab will not impair its structural strength. After such a fire, the injured material may be scraped off, so far as it is loose, and another protecting layer, which is only put on for protection and not for structural strength, can be added.

Another very satisfactory use of reinforced concrete is in the construction of roof slabs for fireproof buildings. The author has recently constructed a factory and boiler house entirely of concrete. Even the side walls were built of hollow concrete blocks. The floors are of concrete, the roof slab of concrete, and even the stairs are made of concrete. The boiler house has a roof with a clear span of 30 feet formed by placing a 4-inch slab on concrete beams stretching across the span of 30 feet. The beams have a depth of 13½ inches under the slab and a width of 7⅝ inches. They are spaced 6 feet 2½ inches apart. The slab is reinforced by ½-inch bars spaced 16 inches apart. Only a few weeks after the roof was in place and before the concrete had attained anything like its full strength a very unexpected and unintentional test of the roof occurred. A steel stack was being erected, the stack being put into place by means of a derrick. The derrick broke, a large gin-pole was broken in three pieces, the stack crumpled up, and the whole mass of wreckage fell on this roof. No injury whatsoever was done to the roof.

Plain Bars vs. "Formed" Bars.

The term "formed" bar is here used as a generic term to denote any style of bar which is not prismatic. A prismatic bar depends

on adhesion or friction for the union of the concrete and the steel. A "formed" bar has shoulders, lugs, twists, swellings, or irregularities which not only more or less effectively prevent the loosening of the adhesion by varying the planes of adhesion and thus varying the direction of the forces which will most probably loosen the adhesion, but they even call into play the shearing strength of the concrete before the rod can be pulled through it, even if the adhesion be destroyed.

Much experimenting has been done to determine the adhesion of concrete to steel. It has been found that when the steel is clean concrete will adhere to it with an adhesion which is equal to the strength of the bar when the length is approximately 12 to 20 diameters. Unfortunately the adhesion, as determined by such tests made shortly after the specimens were formed, has been shown to lack permanency. This may be due to one of three causes. First, the adhesion may be loosened by vibration in the structure—such a vibration as will occur in a railroad bridge or in a factory employing very heavy machinery. Second, some cases in which the concrete was found to have loosened were explained on the ground that water which had soaked through the concrete had made some chemical change in the concrete immediately adjoining the steel which was sufficient to loosen the adhesion. Third, it is reasonable to say that when the structure is stressed to its full load (and especially if it should accidentally be stressed beyond its designed load) the stretching of the bar must be accompanied by a proportionate reduction in its cross-section. Evidently the concrete will be unable to contract so as to retain its contact with the steel, and therefore the steel must separate from the concrete. Probably the number of applications of a given load will have a marked effect on this, and it would be found, after applying a load a very great number of times (say 1,000,000), that loosening might take place even though no evidence of such loosening would occur by the application of that same load a few times. An instance of this sort occurred in a building erected in St. Louis about ten years ago. A 6-inch concrete slab carrying a heavy floor-load was supported by steel I-beams spaced about 8 feet apart. The concrete was reinforced by $1\frac{1}{4}$-inch by $\frac{1}{4}$-inch bars or straps which were hooked over the I-beams and dropped down on a curve toward the bottom of the concrete slab in the middle of the span. The floor safely carried a heavy floor-load for about eight years. Then several panels began to yield. The floor sagged $1\frac{1}{2}$ inches in the middle, which on an 8-foot span gave a very unsightly and unsafe appearance to the

floor. One or two panels caused so much anxiety that they were knocked out entirely. It was at once observed that the concrete peeled off the bars, and it was plainly evident that the adhesion between the bars and the concrete had been destroyed, the load then being carried by the hog-chain action of the straps. It should be noted in this case that for about eight years the floor did its work and carried a very heavy load, thus proving that the ultimate failure was not due merely to poor workmanship, but was due to the fact that the adhesion of the bars was not permanent. This fact has been recognized by the city of Philadelphia in recent specifications for reinforced concrete bridges, in which it is required that "the steel rods embedded in the concrete shall be of some approved shape, especially formed for reinforcing concrete so as to secure an interlocking bond between the steel and the concrete."

It has, however, been very definitely demonstrated that a mechanical bond furnishes a far stronger union between the steel and the concrete than can possibly be furnished by plain bars. About two years ago Prof. Spofford made a series of tests in the laboratories of the Massachusetts Institute of Technology to determine this very point. A large number of specimens, of which forty-five were reported in the published tests, were made by moulding prisms of concrete. The prisms varied in cross-section from 6 inches by 6 inches to 10 inches by 10 inches, and in length from 12 inches to 50 inches. The rods included plain round, plain square and plain straps, also Ransome, Thacher and Johnson bars of sizes varying from ½ inch to 1¼ inches and with a length somewhat greater than the length of the prisms. They were placed in the axes of the prisms during moulding. The load upon the bearing end of the concrete block was distributed by the interposition of a sheet of ½-inch felt between the concrete and an annular steel ring resting upon the platform of the machine. In all cases the rod projected a short distance at the upper end of the block, the pull being downward at the lower end, and this projecting end was carefully watched in order to detect the first evidence of slipping. Although it was intended that the size of the prism should be sufficient in all cases to develop the full strength of the bar, it was found that the largest bars were too large even for the 10-inch by 10-inch prisms in which they were inserted. It was invariably found that the formed bars required a far greater stress in the rod in pounds per square inch of net section than the plain bars. Incidentally it may be mentioned that the Johnson corrugated bar invariably re-

quired a pull from two to three times as great per square inch of net section as a plain bar. These results therefore show: first, that if the stress in a reinforced concrete structure for any reason exceeds very greatly the designed loading and approaches the elastic limit of the steel, a formed bar is far safer than a plain bar, even though the adhesion has not been destroyed. Secondly, experience has proved that the adhesion may be destroyed by any one of three causes, and that it is unreliable for any great length of time, no matter what its tested strength may prove to be on new specimens. Thirdly, that a Johnson corrugated bar will have as great a hold in the concrete as a plain bar at its best, even though the adhesion of the Johnson bar had been utterly destroyed by vibration or any other cause. Incidentally it may be added that the writer has been told of some tests which were made on this line in which the bars were deliberately oiled in order to determine their hold in the concrete under such a condition. It was found that there was practically no adhesion and that the bars could be drawn out of the concrete with an insignificant force. This practically means that if the reinforcing steel should be accidentally smeared with oil or grease the adhesion would be vitiated to some extent, and since the mutual action of the concrete and the steel is absolutely dependent on the intimate union of the concrete and steel at all points, the strength of the structure might be vitiated to perhaps a dangerous extent by some such carelessness during construction. In the tests made at the Massachusetts Institute of Technology all the bars were sandblasted, which of course made the conditions the most favorable for the plain bars. Of course, it likewise made it most favorable for all kinds of bars. But oil on a formed bar would merely reduce its adhesion and not destroy the union between the concrete and the steel. On the other hand, oil on a plain bar will render it utterly useless and endanger the strength of the structure. It is also true that if the bars have been allowed to get rusty to any great extent the adhesion is affected.

Effect of Elastic Limit of the Steel.

There is still much controversy over the effect of the elastic limit on the mechanics of reinforced concrete structures. The writer has no intention of entering into a theoretical argument on this point, but will merely point out the fact that there are some phases of this detail which are beyond discussion. It may readily be seen that when

the steel is strained beyond its elastic limit the union between the concrete and the steel is unquestionably destroyed. If that union depends on mere adhesion, it is certainly destroyed absolutely. If the bars are specially formed, there will still remain a very great resistance, although the structure is unquestionably very seriously weakened, if not actually unsafe. Therefore if we can safely raise the elastic limit, we raise by just that amount the safety of the structure. A great deal of work has been designed using steel which has an ultimate strength of say 64,000 pounds per square inch and using a working stress of 16,000 pounds, and the designer thinks that he has a factor of safety of 4. If the ultimate strength is 64,000 pounds, the elastic limit is probably about one-half of this, or 32,000 pounds. Therefore the real factor of safety is only 2. In other words, if the loading should ever by any mischance be increased to more than double the normal loading, the structure would actually fail, since the elastic limit would have been passed, and, as above shown, the union between the concrete and steel would have been destroyed.

There is a radical distinction between a steel-concrete structure and an all-steel bridge, for example. If a steel bridge be overloaded to such an extent that the unit stress is raised to a little beyond the elastic limit, the structure will not necessarily fail. When the stress is removed, the bridge will not entirely recover its former position, the cross-section of some tension pieces will be slightly reduced, but the unit strength is possibly greater, and the bridge can still do its normal work, although the factor of safety may have been slightly reduced. But when the steel in a steel-concrete structure has been stretched beyond the elastic limit, the steel and concrete cannot return to the same relative positions they previously had. The union is unquestionably destroyed. Under such a condition the formed bar is certainly safer than a plain bar, but a combination of formed bar and a high elastic limit is far better. Several years ago bridge engineers thought they could effect economy by employing high carbon steel in the construction of bridges. Then they found that, owing largely to punching and the irregular stresses produced in plates and structural shapes, the high carbon steel was unreliable, and now a return has been made to the softer steel. But when it is considered that there is no question of punching the steel used for steel reinforcement, and that the stresses in the steel are almost exclusively tensile, the ability of the high carbon steel to safely withstand them cannot be successfully attacked, provided the steel is not actually brittle. The

shearing stresses which may occur in the steel bars are always so far within the shearing strength of the steel that they need not be considered. The Johnson corrugated bars are usually rolled from the same grade of steel as is employed in making railroad rails. There are few metal structures which are subjected to such excessive and irregular stresses as railroad rails. From the standpoint of impact and change of stress there are few metal structures which are so tried. Nevertheless a broken rail is exceedingly rare, considering the hundreds of thousands of miles which are in use. Therefore it would seem like an over-refinement and a needless sacrifice of strength to limit one's self to a grade of steel which has a virtual limit of 30,000 or 32,000 pounds per square inch when it is so easily possible to obtain a material which is thoroughly reliable for its purpose, against which no failure can be reported, and which has a virtual ultimate (by which I mean the elastic limit) of 55,000 to 65,000 pounds per square inch. Such a bar can be as safely used with twice the working strain as would be used with soft steel, or, if it is used with the same working strain, the factor of safety against a possible overloading is practically doubled. Of course, I would not advocate for a moment using a working stress of 25,000 to 30,000 pounds per square inch with the higher grade steel. In fact, Mr. Johnson usually employs 12,500 pounds per square inch working stress with his bars, in spite of the elastic limit of 55,000 to 65,000 pounds and an ultimate strength of 95,000 pounds. But I do wish to express very strongly the opinion that using a working stress of 16,000 pounds for soft steel in steel-concrete work is not only bad designing—it is recklessness.

It will not do to say that overloads will never occur. A cyclone may produce wind stresses in a building which are several times the stresses provided for, and it is a common experience to see a warehouse floor loaded up with a floor-load which is four or five times that for which it was designed.

Stresses in Reinforced Concrete.

It is natural that some engineers should have considerable skepticism regarding the accuracy of theoretical computations of the strength of reinforced concrete structures. The theory is excessively complex, and, secondly, concrete is by some considered a very unreliable material. There is therefore considerable value in the tests which were made recently by Prof. Howe at the Rose Polytechnic Institute, at

Terre Haute, Indiana. These were tests of full-size concrete beams which were purposely made so as to represent commercial practice as closely as possible. Atlas cement, bank sand, crushed rock, and corrugated steel bars were purchased in the open market. The mixing was done by a local contractor of experience with his own gang of men in the manner he ordinarily employed. Instead of using "standard quartz sand," which is so frequently used in test work and which gives results which cannot be compared with commercial practice, he used a sand which, "while containing some 'dirt' in the form of yellow clay, was a fair representation of bank sand used in Terre Haute." The beams varied in length from 12 feet to 19 feet 6 inches. They had a uniform width of 12 inches, but their depth varied from 5 inches to 21 inches. It is difficult to apply a uniformly distributed load to a full-size beam and avoid a tendency to arching action of the load itself, which vitiates the results obtained. A concentrated load in the center also tends to produce a crushing of the beam, which may vitiate the calculations of its transverse strength. The method employed in these tests was to apply two equal concentrated loads, which are symmetrical with respect to the center of the beam, through knife-edges in rolling seats, which thereby produced a constant bending moment between the points of application of the load (excepting the variable moment produced by the weight of the beam). Usually the maximum moment actually developed was somewhat in excess of the theoretical moment as determined by the Johnson formula, probably on account of the fact that the Johnson formula uses 2000 pounds per square inch as the ultimate strength of that grade of concrete and 50,000 pounds per square inch as the elastic limit of the steel (which is in reality the point of failure in steel concrete work), whereas the strength of the concrete was probably somewhat in excess of this, and the steel used actually showed an elastic limit of about 60,000 pounds per square inch. The vertical deflections were read directly from a scale on the side of the beam at the center by means of a silk thread fastened opposite the knife-edges of the end stirrup. Measurements were made to determine the position of the neutral axis for various loadings and the variation of its position for partial loadings. It was very definitely shown that at the commencement of the loading the neutral axis was below the center of the beam. Theory would indicate that for a light loading the neutral axis would be at the center of gravity of an inverted T-shaped section, the sides of the T being formed by extending the concrete at the base of the beam by an amount

proportional to the relative moduli of elasticity of steel and concrete, but it is found that, as the loads increase in magnitude, the axis moves upward very rapidly until cracks commence to appear on the bottom of the beam; then the axis remains approximately in the same position as long as the concrete does not show signs of failure in compression, as indicated by the drop of the scale beam. The special point to which I wish to call your attention in these tests is that in all the eighteen tests there were but six cases in which the actual maximum moment was less than the theoretical moment. Ordinarily the variation did not exceed 3 per cent. Such an agreement between theoretical formulæ and the actual breaking loads of full-sized commercially made beams is not only very gratifying, but is sufficiently close to inspire confidence in the method of the calculations. The method of calculating the strength of simple beams reinforced with steel is practically much simplified by the use of tables and diagrams.

Expansion Joints in Reinforced Concrete.

Another very important feature of this method of construction is the solution which it gives to the problem of expansion joints. It does so by cutting the Gordian knot and omitting expansion joints altogether. This may be safely done on the same general principle as is involved in the practice of street-railway companies in using perfectly tight rail-joints. In the case of the rails the changes of temperature do take place, and they result in severe tensile stress in cold weather and compressive stress in warm weather, but it is easily demonstrable that for such ranges of temperature as will occur the stresses are not unsafe and that the rails can safely endure them. Precisely the same principle is involved in reinforced concrete walls. It is demonstrable that if $\frac{1}{300}$ of the cross-section of the wall consists of steel *properly distributed*, all tendency to contract during cold weather will be resisted by the steel, and it is thus made possible to make concrete structures a mile long, if desired, without using any expansion joints. Experience in these structures has demonstrated that masses of concrete so long that they would inevitably have been badly ruptured by temperature contraction if they had been made of plain concrete, have successfully withstood all ranges of temperature without any cracking. In fact, the insertion of steel in structures merely for the purpose of withstanding this temperature cracking is not only justifiable, but a wise plan, even though the steel was not depended

on to resist any other structural stress. This may explain an element of the design of some of these structures where bars are inserted in places where they are apparently unnecessary for withstanding structural stress. They are inserted as binders to prevent any possibility of the concrete cracking on account of temperature stresses.

In order to have some more definite figures regarding this, I wrote to the engineer of the St. Louis Expanded Metal Fireproofing Company for some explicit examples. An extract from his letter is as follows:

"The rear wall of the Harvard stadium is 1400 feet long, built in the form of a U, and the same contains but one crack at one of the points of tangency, which may have been due to some improper workmanship at this point perhaps. This job has passed through two severe winters, and my report on the condition of same comes direct from Professor L. J. Johnson, the man who had the work in charge.

"There is a retaining wall illustrated in our new catalogue which has passed through one winter and contains no crack. We built a wall in the city here, exposed on both sides to the weather, which is also 300 feet long and contains no crack. It is not that the metal absolutely prevents cracks, but if the metal does not slip in the concrete, the cracks will be very fine and close together, and these will be so small that in the case of the corrugated bar, at any rate, they would not be able to penetrate to the bar."

This is another illustration of the value of a "formed" bar over a plain bar. It is quite possible that temperature changes are one of the most potent causes of the loosening of the adhesion. Corrugations, and especially those which present a square shoulder against any tendency of the bar to move in the concrete, make such an intimate union between the concrete and the steel that temperature changes cannot affect them provided the cross-section of the steel is sufficient to resist the temperature stresses.

Steel-concrete Tanks.

The relative value of steel and concrete in mere tension has already been referred to. An example of this is found in the mechanics of large circular tanks, especially such as are used for gas-holders, when constructed of plain concrete. The principal stress on such a tank when designed to hold water is merely a bursting hydraulic pressure. When this has been sufficiently provided for, all other stresses, such

as wind stresses, will be amply taken care of by the cross-section adopted. The working tension usually allowed for concrete does not exceed 50 pounds per square inch, whereas we readily employ 16,000 pounds per square inch for steel. This means that 0.31 per cent. of steel will accomplish the same work and be even more reliable than the concrete. It means that the tension is provided for at one-third of the cost of an equal strength in concrete. But, on the other hand, a steel-concrete tank is found to be even cheaper as well as infinitely more durable than a plain steel tank. It is not enough in the case of a plain steel tank to provide just enough steel to withstand the bursting pressure. A very thin steel plate might have a sufficient area of steel to withstand the bursting pressure, but it would utterly collapse in the first wind-storm. A steel tank likewise requires constant care and expense for painting and other forms of maintenance, and in spite of all care it is short-lived. On the other hand, a steel-concrete tank when properly made will endure indefinitely, and the cost of maintenance should be absolutely zero. In a steel-concrete tank the concrete not only effectively prevents the corrosion of the steel, but it furnishes the required stiffness and compressive strength (the steel bars taking up the tensile stress), and will permit the amount of concrete to be reduced to a figure which makes it cheaper than a proper design in plain concrete.

Protection of Steel from Rusting by Concrete.

Unprotected steel rusts quite rapidly, especially when it is exposed in damp places, and since concrete is more or less porous, so that water may penetrate throughout a concrete structure, it is frequently assumed that even the embedded steel will rust out. Although it is true that the modern system of reinforced concrete is a matter of the last few years, and therefore there has not been time to determine many of the results which will only appear after many years, there have fortunately been many occasions when the power of concrete to protect iron from rusting has been amply demonstrated. Wm. Sooy-Smith, M. Am. Soc. C. E., reports a small piece of iron set in mortar taken from the base of the obelisk now in New York city which was bright and free from rust after 2,300 years. He also tells of the moving of a bed of concrete at a lighthouse in the Straits of Mackinac, twenty years after it was laid ten feet below the water surface. In this case driftbolts embedded in the concrete were found to be free

from rust. Many tests have been made in which it has been attempted to substitute for long periods of time a corresponding intensity of corrosive action, and although the results of such tests are not conclusive proof, yet they all point to the same conclusion, viz., that if concrete is mixed very wet so as to make it very dense, and if the steel is covered to a depth of an inch or more, there is absolutely no evidence of rusting, unless the steel is exceptionally foul when it is placed in the concrete. There has been considerable controversy over the possible effect of the fine hair cracks which frequently appear in the bottom of a concrete beam even when it is loaded within its designed loading, but the eminent chemist and cement expert, Spencer B. Newberry, has declared unequivocally that there is no danger that such cracks would result in corrosion of the steel under them. He points out the fact that the immediate effect, even when such a crack began to open, would be a slight chemical change and the formation of a carbonate at the bottom of the crack which would effectively protect the steel from any corrosion.

DISCUSSION.

W. F. Ballinger.—Referring to the subject of economy of steel-concrete as compared with steel, I think we might also compare it with wood, in building construction. We have designed and looked after the erection of a great many buildings—principally factory buildings and warehouses—in slow-burning mill construction, and of late quite a number in reinforced concrete. We find that the difference in cost is not usually enough to be prohibitive, whereas the cost of steel beams with fire-proofing of terra cotta or even with concrete as compared with the slow-burning construction is often sufficient to be prohibitive. We have found in our practice that in the use of reinforced concrete we use more steel than we did before we started to use the reinforced concrete construction, just as the trolley cars are more crowded now, although there are a great many more of them, than the horse-cars in older times used to be, because people travel more now than formerly. There are fire-proof buildings being erected by reason of the advance in the methods of fire-proof construction, and particularly of reinforced concrete construction. We have found that the cost is usually not less than 10 per cent. nor more than 20 per cent. greater in reinforced concrete than in slow-burning mill construction. We eliminate all castings used in construction, such as base plates, post caps or saddles, and wall plates, which are a considerable item of expense. Getting it down to a square foot basis, or square foot of floor space, I have figured it out, and in a number of cases find that the slow-burning mill construction would cost, taking the timber, the girder bolts, the castings, the planking (exclusive of flooring), usually about 35 cents per square foot. That is for the interior construction alone of buildings of two or three or five stories; and we find that the reinforced concrete can be built for about 40 to 50 cents,

sometimes more than that, but on the average between 40 and 50 cents per square foot, exclusive of the top flooring. Including the cost of the walls, windows, and finish, which we usually build the same in either case, it only represents a difference in the total cost for a factory or a warehouse building of about 10 or 15 cents per square foot, provided a cement floor is placed on the concrete. With a wood floor, it would cost about 8 cents more than it does for a cement floor.

There is one instance that I might mention—a case of placing an engine on a concrete floor; it was the first engine we put upon a reinforced concrete floor, and I felt at that time as though I was on thin ice, but it seemed to be a case of necessity. We had not designed it originally. We had intended to have a wood floor in the engine-room, with a space of about 8 feet under, sufficient to walk under, in order to get to pipes, electric wires, etc., and in designing our piping and heating plant we found that about the only space that we had for a hot-water generator,—the only desirable space,—would be partly occupied by the engine foundation. So we simply made a change, putting in a reinforced concrete floor as an engine foundation, and the engine has been running now over a year, without any noticeable vibration, and very successfully. We have since done that on several occasions and with equal success.

Emile G. Perrot.—I would like to speak on one phase of the subject of reinforced concrete which has not been touched upon in the lecture, and which I think is worthy of the attention of engineers, and that is the personal equation entering into its construction. The erection of a reinforced concrete building or other structure necessitates a change from the usual methods of construction, and when it comes to the application of the reinforcing bars in such work it would seem that there should be close supervision to insure the bars being placed in the proper position. This of course requires great care either in wiring or banding the bars. In the case of retaining walls, such as in the subway here, some such method must be used to secure them in position, either by wooden templates nailed to the forms or by wiring the rods in their proper position. This question has not been touched upon at all, neither has there been any mention of the improvements made, or of any ideas that have been developed along that line.

We all know that the strength of a beam is materially affected by the position of the bars in the beam. A variation of one inch in a 15-inch beam will affect the strength about 15 per cent. If an engineer in his office figures on a certain position of the bars, and the workmen at the building put them in another position, we have a case where theory and practice do not work together. I do not know whether this phase of the subject has been much considered by engineers, but from my experience I find that it is one of the most serious drawbacks to reinforced concrete, and the development on that line seems to have been overlooked except in one particular case.

There has been a great deal said about deformed bars. I think the European practice of plain bars will be ere long displaced by the later types of bars, and we will be using deformed bars not only in this country, but in all countries. There is no reason why the deformed bar is not a method of reinforcement far superior to the plain bar. Engineers seem to be contented in making improvements in deformed bars, such as the Johnson bar, Thacher bar, and a number of others; even bars in which studs or rivets project from the sides have been used, so that

the tendency to slip is eliminated. As I stated before, there seems to have been but little thought given to removing the personal equation in the execution of the work in the field, and that the mere fact of having to contend with the mistakes that are liable to occur in a building has deterred a number of engineers and architects from using reinforced concrete.

I think that in the future we will find much more reinforced concrete used in building construction, due to the fact that improvements are being made in the methods of construction, and instead of the rods being placed, as is likely to be the case, by inexperienced men in a haphazard manner, they will be put in forms and secured there, so that no amount of tamping or jarring will displace the bars, and when an engineer designs a beam with the rods having a certain center of action, the workmen at the building will have them in that position, by reason of the appliances that will be used. That is one of the phases of the situation which I think demands a great deal of serious attention.

The paper brings up the question of the adhesion of rusted bars, and says that rusted bars did not adhere as strongly as plain bars. I conducted some tests myself to determine that very point, as I understood that the Government inspectors require the rust to be removed from the bars before they will permit them to be used, and I wanted to find out whether they were correct or not. The result of the tests showed that in some cases the rusted bars adhered better than the clean bars. I do not know where Mr. Webb gets his information, but everybody that I have spoken to about the rusted bar seems to be of the opinion that it is all right. Certainly there is no reason why it should not adhere strongly. It has a pitted surface and is simply a deformed bar on a minor scale.

With regard to temperature changes, our experience has been that in buildings that we have built where we run the bars in one direction only in the thin floor plates or slabs, the concrete has shrunk after a period of three or four months, and there would be contraction cracks running longitudinally with the reinforcing bars. In order to offset this, we have been running bars at right angles to the main bars, and in all the buildings in which we have put these cross-bars there have been no cracks appear at all, showing that the theory mentioned by Mr. Webb, that the bars take up the temperature stresses, is perfectly true, and that a thin plate, if reinforced in both directions, will not crack, while if reinforced only in one direction it is liable to crack. We have erected several buildings in which the rods run in one direction and in which I have noticed cracks, while those which were reinforced in both directions have practically no cracks at all.

J. G. Brown.—The paper refers to a building built of concrete reinforced with plain rods, that had failed after an existence of eight years. I have read about that building in the Johnson bar catalogue, and I would like to ask Mr. Webb if he has ever heard of another case similar to it. I understand that there are buildings in Europe that are a good deal older than ten years, and are still in use today, so that if there is not more than one case of failure of that nature, I would think that it was due more to some other reason rather than to structural defects. One failure would hardly warrant the assumption that the use of a plain bar is a dangerous practice. Sometimes we have failure due to the condition of the material that is used. You know, if you take a piece of timber and paint it, so that there is no chance for it to season, a process of fermentation takes place and it will rot or disintegrate, although it takes a long time. Just

in like manner none but seasoned cement should be used. There have been so many buildings built with plain bars alone used that it seems to me there ought to be more than one building fail, if the failure is entirely due to the loss of adhesion between the concrete and the steel. Where the beam sags, of course it stretches, but when I consider the length of that steel and the small deflection possible, I cannot imagine that the reduction of area of the bar can be so very great. And, further than that, we have all seen or read of cases where they have placed deformed bars between blocks of concrete like voussoirs of an arch, and got out of that structure the same strength, practically, as if made of concrete moulded around the bars, which would make it appear that the strength of the beam does not depend entirely on the adhesion of the bar.

Of course, there is no question but that a deformed bar appeals to the mind to be a very good thing. Personally, I believe in it. But, at the same time, there are so many buildings built of plain rods that I would like to know something more definite as to their being unsafe, or have some more data before advocating a deformed bar to the exclusion of plain rods. While I do not believe a whole lot in the adhesion of steel to concrete, neither do I believe in devices riveted to pieces of iron, but I do believe in a mechanical bond. I think the concrete and steel act structurally principally on this account.

H. H. Quimby.—The paper is somewhat meager in its consideration of a very important question connected with the subject—the durability of reinforced concrete structures. The reason may be that data respecting it are not plentiful because the practice is young, but there are many such structures accessible to all who care to study their action, and much can be learned by examining them. Concrete is liable to cracks which may not always, but certainly often do, indicate approaching dissolution, and in several examples of reinforced concrete in this city and neighborhood the action of internal or external stresses, or both, can be seen in the development of cracks. The oldest is only three years old and one is less than one year old. While undoubtedly reinforcement sometimes prevents cracks, it certainly does not always do so, and probably sometimes causes them. Therefore the design of such work should include provision for stresses due to other forces than mere dead weight and live load. These other forces are internal ones due to unequal shrinkage in setting and unequal change of volume from temperature.

In the present state of the art of making and placing concrete even a fairly uniform grade of work cannot easily be obtained, and internal stresses are almost certain to develop. If a steel bar be embedded in wet concrete and the structure be in a situation where it will ultimately dry out, the concrete will contract on itself and on the embedded steel, producing compression in the steel and initial tension in the concrete. If, now, there be added—as in the case of a beam—additional tensile stresses from load, the cohesion of the concrete may be overcome, although the calculated stress in the steel is far within the limits of common practice. Then, also, some members of a structure may be entirely exposed to the atmosphere and its influence, while adjacent portions are so protected that only one surface is exposed, and thermal changes will consequently be not uniform, perhaps rupturing the material where the stress is tensile. Again, struts or beams may connect heavier bodies that are so stable that the contraction of the beams from drying out or from temperature may not be able to move them. The concrete will then certainly open.

All of these causes are operative and the effects clearly discernible in the neighborhood examples referred to, where cracks are observed to be appearing and extending and threatening.

One of the theories advocated in the paper may be questioned. It is that reinforcing steel should be of high elastic limit. What really should be high is the modulus of elasticity. The extent or range of the elasticity itself is of little relative importance. The impression is very general that a steel with a high so-called limit of elasticity will stretch less than one of low, but this is a mistaken impression. The fact is that a high steel—say, 60,000 pounds elastic limit—will stretch just as much under its working stress—say, 16,000 pounds per square inch—as a soft or 30,000-pound steel. The actual and inevitable stretch of the reinforcing steel under service loads is a vital element in the life-struggle of the composite girder. If such a girder be without cracks, the concrete by its tensile strength will sustain the bending moment, and the steel will generally not be stressed until the cohesion of the concrete is overcome. Then the stress will get into the steel at a crack in the concrete and be localized there—perhaps actually changing from compression to tension. Tension will stretch the steel at the point where the stress exists—very slightly, but still actually—and any stretch of the steel will loosen its hold in the concrete immediately adjacent to the crack. Almost every one who has witnessed tensile tests of steel specimens held in hatched grips has noticed the gradually increasing stretch in the grips from the back to the front as shown by the slip in the hatching. The action in the grip of the concrete is similar, with the difference that very little stretch will altogether loosen the grip of the concrete by crumbling it away, as is very clearly seen in transverse tests, where the load is applied slowly under control. This loosing of the grip permits the stretching of the steel to occur over an increased length, and thus extend the loosening operation. The destructive tendency thereby becomes continuous and progressive under a constant unit stress.

It seems clear, therefore, that the steel that will stretch the least under a given stress is more valuable than one that stretches more and merely has the quality of stretching farther before taking a permanent set, a condition of service that is so remote in probability that it is hardly a legitimate basis for a claim of superiority.

Apparently the way to increase the coefficient of elasticity of steel is to stretch its fibers, while cold, beyond the elastic limit. This will, of course, reduce the cross-section, but it will raise the allowable unit stress and reduce the danger of injurious action in service. The logical deduction, then, is that the best reinforcement for concrete is the rod whose shape gives the most positive lock in the concrete (it may be the one advocated in the paper) stretched cold to a point to be determined upon as the most economical.

Mr. Webb.—There are very few reinforced concrete buildings now constructed which already have an age of ten years. The real test is a matter of years, rather than what the concrete will do during the first month or two. That is why tests which have been made using formed bars and also using plain bars give nearly the same results. At least the discrepancies are not very great; and that is because when the concrete is first formed the adhesion certainly is large, and is perhaps enough, so that if it could be permanent it would stand for all time. I called attention in the paper to the fact that for

eight years that building stood up to its work all right, but at the end of eight years it began to fail; and what I am expecting is that as time goes on there will be more and more buildings fail which are constructed with plain bars, and it may even result in a slump in this sort of business; people will be alarmed at it. But, nevertheless, if they come to analyze why it is, I think that they will find that it is because the adhesion has failed, and therefore you must have a style of bar which does not depend on adhesion alone.

COMMUNICATED DISCUSSION.

F. N. Morton.—In the discussion some remarks have been made upon the necessity of cleaning the steel from mill scale and rust before embedding it in the concrete. There is evidence to show that there is no occasion for this, as it would appear that the scale was removed by the action of the concrete. In a lecture delivered before the Armour Institute, Chicago, last year, Mr. J. W. Schaub remarked that when a rusty bar of iron is embedded in cement mortar it will be found at the end of fifteen or twenty days to be perfectly free from rust, the iron apparently giving up its oxygen to the cement.

At a recent meeting of the Royal Institute of British Architects, a discussion upon the subject of reinforced concrete brought out the statement that oxide of iron cannot exist in contact with concrete, and that rusted bars embedded in concrete will, in the course of a month or so, be as bright as new, the rust having been deoxidized with formation of ferrite of calcium, which forms a protective skin around the bars.

PAPER No. 1008.

SANITATION OF OFFICE-BUILDINGS.

HENRY LEFFMANN.

Read April 1, 1905.

SOME time ago I saw a street-car advertisement with this catch-phrase: "You pass as many of your waking hours in your office as in your home; why not make the former as comfortable as the latter?"

The philosophy of the proposition impressed me, and, together with the almost daily opportunity afforded me during the last four years of observing the operation of a modern office-building, led me to some investigations as to conditions of comfort and healthfulness to be found therein.

Without doubt modern construction has improved these conditions in some respects. The old-fashioned office, generally adapted from an abandoned fashionable residence, was dingy, badly ventilated, badly heated, and poorly provided with what are now ordinary conveniences. It is, however, entirely consistent with modern progress, that what is gained in one direction is lost in another. The old-fashioned office had an element of independence and individuality. The conditions were fairly under control of the occupant. The modern building exemplifies the communal tendency; the tenant is merely one of many.

In presenting this note, for it is nothing more, I wish to be direct and specific. I have noted some conditions in office-buildings which I think should be condemned, and I propose to do this.

The most important questions for the tenant are the water-supply and the drainage. In a city such as Philadelphia the former is primarily bad, and in the highest type of office-buildings installations are made to remedy it. These sometimes extend only to furnishing a filtered water, but in some cases an artificially cooled supply is also installed. The question at once arises as to what guarantee the tenant has that this filtration is more than nominal. It is now well known that the filters commonly installed on a small scale soon fall off in bacterial efficiency and give no warning. When, in addition to the filtration, a cooled water is supplied, the question becomes much more momentous. How is the cooling done? If it is done after the manner of railroads and steamboats, by dumping ice into a tank con-

taining unfiltered or roughly filtered water, the danger to public health is evident.

Even when the tenant uses the old-fashioned water-cooler the protection is apt to be slight. In office-buildings in which this system is used ice is delivered in blocks of assorted sizes at an early hour in the morning. In some cases these are simply dumped on the pavement to be taken in when opportunity offers or when the janitor is ready. In other cases, as in the building in which I am located, metal buckets are used. This latter method seems neater, but it is not likely to be so. I recall here the lines in Goldsmith's "Deserted Village":

> "The bed contrived a double debt to pay,
> A bed by night, a chest of drawers by day."

So these buckets, apparently clean, hold the ice in the morning, and perhaps the slops of the corridor and office scrubbing in the afternoon. The pieces of ice are often rinsed, but rinsing with Schuylkill water is scarcely to be called cleaning. We may have some hope of better things in this respect, but even filtration of the city water-supply will not wholly remedy the trouble, for, as I know by observation, the rinsing is often done in the wash-basins in the toilet-rooms.

To avoid the danger, as well as the disgust which the knowledge of these practices has provoked, I have for some years followed the plan of using the ice only by intermediate contact, that is, placing it in a small tank with a bottle of water of known purity. The temperature is not as low as that obtainable by direct admixture of ice with water, but it is quite low enough; indeed, there is no reasonable doubt that extremely cold water is unwholesome.

The ventilation and heating of these buildings are problems too extensive to be more than touched upon in this communication. Fortunately the economy and convenience of steam or hot-water systems have led to their general installation, and thus the professional man finds at least one advantage of his office over his home: he is not obliged to breathe the emanation of a hot-air register.

The ventilation is more or less unsatisfactory in the inclement seasons of the year, but it is usually at least as good as the home, and as the total number of hours of occupation of the office per day averages less than that of the home, the condition is a little in favor of the former in this respect.

The toilet-room conditions have greatly improved of late years. The open plumbing and the almost total relinquishment of woodwork

have simplified the condition of cleaning and have also restricted the development of insect-life. The wooden inclosures formerly regarded as essential presented abundant opportunities for the multiplication of roaches, ants, and similar insects. The introduction of metal, cement, and terra-cotta construction has restricted very much the invasion of rats and mice. Only those who have followed rather closely the sanitary studies of recent years can realize how these house vermin are connected with the distribution of disease. If the money spent in any recent war had been expended in a war of extermination against mosquitos, flies, mice, and rats, great benefit would have resulted to mankind.

The condition of the cellar of an office-building is a matter of importance, yet it is one about which very few tenants concern themselves. It has been brought strongly to my notice because I have been obliged to keep some articles of occasional use in the cellar, and have been obliged to go there occasionally. Cellars are rarely in good condition anywhere, but in office and institutional buildings in active use they are the receptacles of all kinds of discarded and broken-down material. Old paper, rags, broken desks and chairs, bottles, boxes —in short, a thousand and one things that should have been burned or sent to the waste-utilizing works. In the compact mass of these articles vermin—large and small—find a home, fungi grow and impregnate the ventilating shaft with their spores. I have often been puzzled by the indifference exhibited by the insurance companies to the cellar conditions. They are not interested in the sanitary aspect, but the fire-risk is much increased by the accumulation of rubbish. In the interests of safety to health and property, the use of cellars for storage of anything but materials used in the operation of the building should be forbidden.

It cannot be at present expected that the owners and operators of office-buildings should do more than maintain the routine cleanliness of toilet-rooms, but every user of them should bear in mind the dangers of communal use in such matters. Few outside of the medical profession know of the results of venereal disease or of the possibilities of communication through circumstances other than those for which the individual is responsible. The condition is one of those unfortunate ones in which a few see the danger but cannot arouse a general interest in the stringent measures necessary for complete reform. One point, however, in regard to sinks and other toilet arrangements that is receiving better attention of late years is the matter of

light. It used to be thought sufficient to put such things in any dark, unventilated corner. In such places dirt is allowed to accumulate, but when they are well lighted the neglect is apparent and the esthetic sense will often prompt a protest even if the sanitary consciousness does not. The cleaning methods of office-buildings will bear considerable improvement. So far as the toilet-rooms are concerned, it would be well if they were so constructed as to permit of complete washing with a stream of water thrown over everything below six feet from the floor, the room being drained so that the water will run off completely.

In the routine cleaning of offices and corridors the opportunity for improvement is also presented and the means thereto are at hand. The methods in vogue in most buildings are substantially those that were probably used in the Temple Library at Nippur when the brick-dust was swept up, possibly by the unfortunate Lushtamar, the addressee of the letter that never came. Within the past few years a system has been devised that is so simple that it is a wonder it was not devised long ago. The vacuum system of removing dust is the proper one for this work. It gets rid of the material. The ordinary system merely stirs it up from day to day.

Some sanitary questions in regard to office-buildings rest with the tenants individually, not with owners or operators. One of these is the matter of ordinary neatness and care in the use of rooms, corridors, and elevators. I have seen anti-spitting notices in elevator-cars, and on inquiry have learned that even these requests did not succeed with all persons. The tenant of an office adjoining mine was a flagrant violator of propriety in this respect, spitting without restraint on the floors of offices, corridors, and elevator-cars. He was an inveterate smoker, and I think there is not infrequently a relation of cause and effect in this.

Among the improvements to which these large buildings are susceptible, the utilization of the roof has seemed to me worth considering. Such suggestion will, with many persons, carry with it the concomitants of beer and vaudeville, but it seems rational to make some use of the large area which the roof offers. I never see the new Central High School without regretting that the large roof surface was not utilized for a playground. Such plan is practicable and advantageous. In ancient times the people used to enjoy themselves on the house-top, and the denizen of the modern city might do the same.

I have sought here to call attention to some of the defects that I

have observed in the modern rookeries that are so marked a feature of city life. The estimable gentleman whose statue overlooks the city from the apex of the City Hall intended that Philadelphia should be a "green country town." He would be much astonished if he could see it now, but his feelings would probably be more admiration and approval than condemnation, yet we must not allow ourselves to be blinded by the appearance of material progress. In the midst of general advance in manners, some of the objectionable older customs have remained and some new ones have been developed. The price of health, like that of liberty, is eternal vigilance. Communal conditions bring convenience, economy, protection of person and property, but they also bring more intimate contact and more facility for communication of disease. To some the issue may seem trifling, but it is not so. The street-car phrase, intended only to secure customers, is true text for a sermon, and a due regard to it will save doctors' bills and suffering. The cost of offices is such that the tenant is entitled to good service; the methods of sanitation are now well enough understood to leave no excuse for their non-observance. Something rests with the tenant, and each one should practice such personal methods as will not offend either the esthetic sense or the personal safety and comfort of his neighbor.

DISCUSSION.

E. G. Perrot.—Can the author of the paper give us some idea of the practical operation of the system of cleaning to which he referred?

Henry Leffmann.—I have seen the circulars of the company and a statement of the character of the material collected by the method. It is by suction, drawing the dust into a receptacle. Each floor, or other convenient section of the building, has an attachment to the general exhaust. Similar systems, on a small scale, have been long in vogue in laboratories, and no practical difficulty in their extension should exist. The material collected is, of course, miscellaneous in character. Among the interesting data given in the circular are the results of culture of the dust, showing many living microbes, including bacteria belonging to the "pus-formers"; that is, those which cause boils and sties. These microbes are floating around and attach themselves to the skin. By collecting them by this method they can be burned.

This system is so great an improvement upon all others that its installation can only be a matter of a short time. It appeals so to the sense of cleanliness. The method of blowing air, which has been adopted in some buildings and in some railroad service, is really not a method of cleaning at all; it is simply a method of raising the dust temporarily; something like that which we see carried on in our streets.

H. A. Foster.—Any one who wishes to inspect the vacuum method can see

it almost any day in West Philadelphia, cleaning Pullman cars, carpets, etc. I have seen it in operation.

William McClellan.—I think it can also be seen at Wanamaker's. It is used there on different floors, in the drapery department and similar places. I have noticed the men at work at it. A trough runs around the floor and the dust is drawn through this into the basement. The exhaust air is obtained by a special form of pump.

J. C. Wilson.—I have seen the system in operation in a hotel in which it was claimed that it was successful. I noticed, however, that it was not taking up much dust from a carpet that had a heavy nap, and on calling the operator's attention to this fact, he said that probably the suction was being operated on another floor. It seems, therefore, that there is some danger of dividing the draft so as to make it ineffective.

E. M. Nichols.—In Indianapolis I saw a portable suction apparatus, a plant on a truck, a gasolene engine, Root's exhauster, etc., with hose running up the windows in the building. I did not have time to investigate closely, but everybody seemed to think that it was effective.

H. Leffmann.—Of course, the process has limitations; the pressure of the air being fifteen pounds, there is the limitation of the vacuum. Compressed air can be carried to a much higher pressure, so that the supply can be made more abundant. The defect indicated by one of the speakers is simply due to the installation, just as it is in many cities with water-supply: the hydrants will not run on every floor, because there is not enough pressure. That could be remedied by not attempting to do too much at once. That is a part of the discipline of the house, to see that servants do not attempt to sweep many rooms at once. The trouble was not a defect in the plant but in the method employed in operating or applying it.

W. F. Ballinger.—Dr. Leffmann touched upon the heating and ventilation, but no one else has spoken on that subject. I think that nearly all the office-buildings are heated by direct radiation, only a few buildings by indirect. I know of only one in this city that is heated by the coil system; that is, heating the air in the basement and having some method of getting cold, pure or screened air to the coils, and then by means of fans and a system of ducts or flues sending it into all the offices. I think that in the only building in which this is done (a sixteen-story building) there are two systems; one for the first eight stories, and another for the ninth to the sixteenth stories. Probably Mr. Nichols can enlighten us further on that point; I have in mind the Real Estate Trust Building, which is heated by this system. I know of many buildings in which three or four systems are employed, but I do not know how successful they are in these sky-scrapers.

Mr. Nichols.—So far as the Real Estate Trust Building is concerned, I had something to do with the installation of that plant, and it is the only large office-building in the city that has one in operation. In the original building, which was on the corner, there was only one set of fans, which supplied the entire building to the top floor. There was some complaint at times in regard to the results, but as a general proposition I think that the tenants are well pleased. It is not an automatic apparatus except in a few rooms in which the engineers designed and installed such a form as a matter of convenience in order to investigate it.

The original plant put in for controlling the temperatures in the rooms did not seem to give the greatest success. It is now done largely by hand.

I am not so familiar with the installation of the plant in the new building, having had nothing to do with it, but I believe it has given some trouble. Each floor has a separate duct leading from the basement. The flues are carried above a false ceiling in the corridors, and they branch out underneath near the ceiling of the rooms, and each room has its exhaust ventilators at the baseboard. In the outlet they have a large exhaust fan which to a certain extent exhausts the vitiated air and helps to ventilate, but that does not amount to much in this installation, it being almost entirely a process of forcing the air in. The only criticism I have ever heard is that those who operate it say it takes a tremendous amount of fuel to heat the building.

C. H. Ott.—The City Hall is heated by that particular system as described, and has been for some twenty years, I think.

The President.—This is a very interesting subject for discussion, and, as has been stated by one of the speakers, the matter of cost governs largely in buildings of that nature. If any one has any comparative data showing the cost of the two systems, I think the figures would be of interest in this connection. I suppose it is a matter that none of us will question, that the indirect system will cost more than the direct system, but, as applied to high buildings, possibly not many of us have data at hand.

Mr. Foster.—Some years ago I had quite an intimate connection with a building out of town that was heated in this manner, and there was very serious fault found with it as to the matter of cleanliness. It seemed to be utterly impossible by any method of filtering or washing the air to take out all the fine particles of dust. It was frequent during the day to have to wipe it off the books. Possibly the apparatus was imperfect, but I know that measures were taken to eliminate the dirt, and the engineer spent a large amount of time devising different kinds of nozzles to wash the air, and also tried cheesecloth screens of all kinds. The air was taken up about fifty feet from the ground. In that town, which was rather smoky, it was found very difficult to keep the air clean enough so as not to cause discomfort in the rooms. But the heating was almost perfect.

M. R. Pew.—I have an office in the Real Estate Trust Building, and have not noticed trouble with dirt. The ventilation is excellent and we are located on the thirteenth floor, so we do not get any street dust. The only thing that has proved annoying is the noise. When the heat is turned on in our rooms (I do not know about the majority of them, but both of our offices have automatic controlling apparatus) as soon as the thermometer gets below 70 degrees, we suddenly hear a roar, beginning as the heat comes in, and—especially in using the telephone—it is sometimes exceedingly annoying to hear that constant roaring. In cold weather it is, of course, much more noticeable than when the weather becomes milder. The noise, however, has been very frequently quite annoying.

Mr. Ballinger.—The noise to which Mr. Pew refers may have been the working of the electric thermostat which operates to close the register, allowing the air to come in or out; but, if so, it would only last a very short time. Mr. Foster just spoke about the condition of dirt. He made the remark, however, that

it was in a smoky town. I happen to have had some experience with this method of cleaning and ventilating, and where we have taken the air from a height, such as he mentioned, of fifty feet above the ground, we have not had much difficulty from dirt, especially after passing it through cheesecloth screens. I think that is done in the Real Estate Trust Building here. They are made in accordion style of frames—that is, zigzag, so as to get a very great area. If a screen is simply put flat across the inlet, it will not pass a sufficient quantity of air. The method is more or less effective; that is, in the washing apparatus, probably more effective. I saw a washing apparatus to-day in operation in a laundry, and the proprietor informed me that it is very effective. This is used especially in the summer-time, both for cooling the air and washing it, so as not to get the dirt from the street or otherwise on the laundried goods. A mass of coke 18 inches thick with a height of about 8 feet and 10 feet wide is in a sort of cage; water runs over this and a centrifugal fan sucks air through it into the building. Such a method as that might be tried for heating or cooling. I think this system of heating gives purer air in a building, and this will keep people awake and lively.

Mr. Nichols.—There is a building next door to us here that has the direct-indirect system, which was installed a few years ago, and it was regarded as a considerable nuisance on account of the uncertain method in which the apparatus was handled, and the liability of pipes freezing if shut off in cold weather. The most satisfactory system for heating any building is the combination of the two; that is, enough of the indirect to give sufficient ventilation for sanitary purposes only, with an additional direct radiating surface in the room to bring up the temperature when it is required. That gives the most satisfactory service of all.

I think that the noise complained of by one of the speakers is entirely due to the very high velocities used at times. I think he will notice it to be greatest in cold weather, when the fans are running at high velocity, in order to supply enough hot air to heat the rooms properly. That is one of the difficulties that arise in extremely cold weather. A pressure which generates a velocity into the rooms as high as 700 feet per minute will make a considerable noise. With a velocity of more than 300 feet per minute noise is pretty sure to be developed.

Mr. Ott.—What would be the proper temperature for an office-building, and what for a dwelling?

H. Leffmann.—I do not know that I can answer that. The room temperature is put by some authorities as high as 77 degrees. Perhaps that is a little high for many persons. I think very much depends upon personal feelings, and upon the condition of the individual. Probably it should not be below 70 degrees, and it should not, of course, be above 80 degrees. Somewhere between those two points would doubtless be a satisfactory temperature, but there are so many conditions that no definite figure can be made out. An active man in the best of health will resist the cool air. On the other hand, even a man in good health, in an office, and to a certain extent working under a low pressure, in a relaxed condition, probably will need a little higher temperature. I think Mr. Nichols is right in his views that a combination of the two methods of heating is a remedy. Personally, I am very much in favor of a radiating object in the room, not relying entirely upon the filling of the room with warm air flowing in,

but relying upon a fairly heated but not very hot surface. This was one of the advantages of the old-fashioned stove; it was a radiating surface as well as a ventilating machine. When the door was opened the air was drawn up through the fire, and a certain amount of ventilation was thus obtained.

J. B. Hutchinson.—It occurred to me that sometimes we are apt to be a little too warm. In the summer-time, when the thermometer is about 75 degrees, when we are dressed lightly with thin clothing we are fairly comfortable, and yet here we are in the winter season, wearing heavy clothing with the thermometer up to 75 degrees, and many of us are comfortable. As for myself, I always feel more comfortable when the temperature gets down to 60 degrees.

H. Leffmann.—It should not be forgotten that the discomfort of a warm day, as when the temperature is as high as 98 degrees, as in midsummer, is not due to the temperature alone, but also to the saturation of the air with moisture—the humidity. When the air is humid the heat or cold is felt more than when the air is dry. A temperature of 100 degrees can be borne in some parts of this country easily. When the perspiration evaporates rapidly, the body is able to resist the heat. The same holds true when the temperature is extremely low and the air damp, or when the temperature is high and the air humid. In both those conditions the surface of the body is not able, owing to lack of evaporation, to resist the cold or heat, as the case may be, and hence a sense of discomfort, not wholly due to the temperature, comes into play.

A Member.—Bearing out what Dr. Leffmann just said—while South recently I wanted to see some of the country, and I took a bicycle ride, and if I remember correctly, the temperature was 128 degrees in the sun. I rode about six miles and did not feel any more discomfort than I have here when the temperature was 98 degrees, the air there being drier and the climate of a different nature.

The President.—Probably the effect of the humidity or dampness of the atmosphere on the temperature required for comfort is seen by a comparison of English and American text-books on heating and ventilation. In England the temperatures recommended are from 7 to 10 degrees lower than those recommended in America, which are 70 to 73 degrees. The humidity of the English climate is not paralleled in general in our country, and we require, therefore, for satisfaction and ease, a higher degree than would be required in that damp climate.

COMMUNICATED DISCUSSION.

Wm. Copeland Furber.—In discussing a broad subject such as the one Dr. Leffmann has presented to us, it is but fair that the observations be based on more than one building. Without intending to take one building as typical of the whole, I fear that the author of the paper has unconsciously fallen into this error, and from the conditions he describes it is not hard to locate the building on which he bases his observations.

In a general way, it may be said that the maintenance of an office-building is like keeping-house, and because some houses are poorly kept, it is not safe to infer that all houses are badly kept. The building I think the author has in mind is probably one of the original office-buildings in this city, and in respect to planning and sanitation is far below the accepted standard of today. Speak-

ing from a wide knowledge of the mechanical and sanitary equipments of office-buildings in this city and elsewhere, I think it can be safely said that the standard of cleanliness is very high. The equipment of modern office-buildings leaves little to be desired. They are usually designed by men of ample knowledge and experience and no stint is put upon the expenditure of money to secure the best results.

Filtration of the water-supply is usually made by means of one of the mechanical filters, and if properly cared for should afford good results. In the more recent and larger office-buildings the water-supply is filtered and cooled by refrigerating apparatus, which is similar to the apparatus employed in ice-making plants. Unless gross carelessness is permitted there is little or no danger of contamination or infection—and here again it becomes a question of good housekeeping.

In some of the smaller and older office-buildings which do not contain a complete mechanical equipment, and where light and power are obtained from the outside, a lower class of labor is employed, and such buildings are usually the ones where lax conditions prevail.

If a visit be made to the first-class office-buildings in this or any other city, the basements and mechanical departments will be found to compare favorably in regard to cleanliness and appearance with that of the mechanical department in the hold of a first-class passenger steamship. A good engineer usually takes very good care of his mechanical plant, and therefore takes pride in showing it. Some of the more pretentious office-buildings make the engine-room and basement a sort of show place, and tenants are welcomed to inspect it.

The organization of a large office-building is a complex one, and may be said to resemble that of a ship. The man in charge of the building is designated "Chief Engineer" or "Superintendent," and every one employed in the building reports to him. The Superintendent has entire charge of the building, purchases all supplies, such as coal, oil, lamps, waste, soap, and paints, and the thousand and one things needed to supply and repair the building. Sometimes he rents the offices and deals directly with the tenants. Under him come the engineer, the electrician, the firemen, the painters, the plumbers and steam-fitters, the carpenters, the window-cleaners, and the janitor and scrubwomen. The janitor, usually a man, supervises the scrubwomen and office-cleaners, who report for work about four in the afternoon, work until eight in the evening, return at seven the following morning, and work until 9 A. M. These women sweep and clean the offices at night and dust them the following morning. They also scrub the marble floors and stairways and do whatever cleaning is necessary. In a large building a great deal of repair work is constantly going on which requires carpenters, painters, electricians, pipe-fitters, and machinists; in the smaller buildings these functions are performed by one or two men, while the large buildings have men of almost every building trade.

In the matter of plumbing fixtures and equipment, the modern office-building is very complete; the latest development of sanitary science being almost universally employed, and the rigid rules of the Health Boards leave little room for laxity in sanitary requisites.

In the sweeping of offices and apartments the newly devised system of vacuum exhaust, referred to in the paper, is a great advance on the method of the broom.

In this method an exhaust pump in the basement is connected to vertical iron pipe mains which have outlet connections on each floor at convenient intervals for attaching a flexible rubber hose. This rubber hose has an inlet nozzle with a broad, flat, narrow orifice, something like the edge of a shovel. By pushing this along the floor or carpet, or holding it against curtains or draperies, the dust is rapidly drawn in and carried to the basement. When thought is given to it, it seems remarkable how long it has taken to design this simple device.

In office-buildings the heating apparatus is usually the direct method of local radiators in the rooms. Exhaust steam from the mechanical plant is largely used, supplemented with direct live steam in very cold weather. For rooms in which no great number of people are employed this is satisfactory, but when frequent changes are required it is not sufficient. The mechanical difficulties and the expense of the indirect "fan system," or "hot blast" system, as it is sometimes called, are usually sufficient to preclude its use for all the offices in the building, though it is frequently used for the large rooms and auditoriums which may be contained in such buildings. The necessary employment of large ducts in vertical, and particularly horizontal, directions makes their use difficult and expensive, and the carrying of air under slight pressure long distances from a mechanical standpoint is uncertain and unsatisfactory. The most successful method is to divide the building into horizontal zones, and to have the fans and steam coils divided and supply each zone from its own local center. This method reduces the size and lengths of the distributing ducts and makes their operation certain. The objection to this method is the loss of valuable space usually occupied and the cost of installation. This method of local centers is employed in the new Hotel St. Regis in New York city, a seventeen-story building, which is probably the most elaborate hotel building ever constructed.

The fan system of heating is successfully employed in heating and ventilating assembly rooms and auditoriums, theaters, churches, school-houses, stores, factories, and rooms in which large numbers of people are housed, and it is at present the only practicable method for positively changing the air in such enclosures. The basement and first floors of the latest department stores are usually heated in this way. I do not think, however, that the typical office in an office-building presents any difficulties in the way of ventilation which cannot ordinarily be met by the opening of a window.

H. Leffmann.—Mr. Furber's remarks are timely, but it must not be forgotten that there are office-buildings and office-buildings. For one of the excellent kind, new and modern from cellar-floor to roof, there are probably two of lower grade; many of the latter class being merely old buildings altered. When the location is such that the class of tenants is made up of attorneys or physicians of large consulting practice, officers of large corporations, or promoters who desire to impress intending investors, the rental can easily be fixed at a sum sufficient to cover high efficiency of operation, but a large class of tenants regard economy as the most important point, and in saving say a hundred dollars on yearly rent, do not take into account the doctor's bill that may result.

Paper No. 1009.

THE ELECTRICAL ENGINEER IN HEAVY TRACTION WORK.

WILLIAM McCLELLAN (Active Member).

Read April 15, 1905.

It would be a very bold and probably a very foolish person who would attempt much of a prophecy as to even the immediate future of electric traction. From the ordinary electric street-car of but a few years ago we have advanced to the recent development of the heaviest locomotive service. Apparently we have opened up or broken ground in every field in which this branch of industry may exert itself. Not only has this new engineering come, but also a new engineer. A large class of men, with little experience in what may be called practical railroading, have attacked the most complex problems in this branch of work and solved them satisfactorily. While they have made free use of the large amount of experience and information obtained by the workers in steam railroading, certain peculiar features of their problems have caused them to develop along somewhat different lines, and invent somewhat different methods. A discussion of these is the purpose of this paper. There is no sharp line of division between "Heavy" and any other form of electric traction. The term has been used often but never defined. It has been tacitly assumed to include all service which is comparable in schedule, speed, and load with what we mean when we say "railroad."

There seems no doubt that, in the near future, many railroads will substitute, either wholly or in part, electricity for steam as a motive power. This does not mean that there will be any very rapid change. For many years, however, almost all railroads have managed certain species of short haul and small schedule traffic with little or no profit, and there has seemed to be no remedy. Time after time different roads have tried motor-cars of various types, but have not succeeded in mending matters. In late years the competition of electric roads has aggravated the trouble and now a solution is almost demanded in many places. As a result we hear much more than usual about gasoline cars, steam cars, electric cars with generating plants on board, compressed-air cars and the like. No one can say with certainty, just now, from what direction the final solution will come; but it is probable

that the trolley in some form will win out, unless the much-longed-for, durable, light, efficient storage battery appears. The action of several of our great Eastern roads in acquiring electric systems as feeders or otherwise is a sure indication of the trend of thought and policy. It is certain that while there may be other methods that will solve the problem, the electric system has advantages in these critical cases that no other system possesses.

No one has shown that the electric system, under all circumstances, is able to withstand the steam locomotive on its own ground, that is, modern trunk line and freight service. As long as we do not demand too rapid acceleration, and average speeds greater than 60 miles per hour, with few stops, the steam locomotive is a worthy competitor, to speak very mildly. Moreover the steam locomotive is not deteriorating, but is making very decided progress. Thousands of dollars are being spent today on experimental investigations for its improvement. And this is being done by men for whose foresight we have the greatest respect. A fine view of the new elevated freight line of the P. R. R. can be had from the office of the writer, and he has a continuous object-lesson in the hauling capacity of the steam locomotive. There are other conditions, however, that are hastening a change which are now receiving scant attention. For example, a road that is in the vicinity of a large water-power, and this means within one hundred miles, thanks to modern methods of power transmission, would find the change more profitable than one that would have to haul its coal under any plan. Again, in most mountain regions there are numerous small water-powers, that separately amount to nothing, but which if developed and brought into one system, would prove valuable properties. These small water-powers would be especially valuable to railroads on account of the distribution of loads over considerable areas. Certainly the enormous amount of power thus represented will not always be allowed to waste, for a feasible plan for utilizing it can be found. It is a serious question if it would not pay many roads to acquire possession of some of the more important of these properties now. In referring to conditions that act to bring about the change, we do not discuss those comparatively few cases where roads have been forced to adopt electricity on account of municipal pressure, stress of public opinion, and the like. Nor do we discuss the tremendous influence the present enormous investment in steam systems has, both in apparatus and trained operators, in preventing a rapid change.

The question of change of equipment is now a matter of finance, rather than of engineering. Electrical engineers are ready to equip any kind of road, no matter how heavy the service, with electric power. As intimated before, however, the most conservative are not ready to guarantee equal economy under all conditions. The particular motor system to be adopted would naturally have a great influence on this latter factor. Just at present, classifying them very generally, there are five different systems offered for adoption. These are:

(1) The *Direct Current System,* such as is used on most of our street railway and interurban lines.

(2) The *Alternating-Direct Current System,* which so far as the car is concerned does not differ from the first. The electromotive force is generated by an alternator, transmitted at high potential to a substation, and changed into direct current by a rotary converter.

(3) The *Alternating-Direct Commutator Motor System,* which is a low pressure system, the motor running on alternating current in interurban districts, and on direct current in the city districts or where dense traffic obtains.

(4) The *High-pressure Trolley System,* chiefly alternating, in which the trolley pressure has been pushed to 6000 volts, though 3000 now seems to be commercial.

(5) *Polyphase Systems,* requiring more than one trolley or collector.

It would be interesting to discuss these systems, but this is not our purpose now. We rather propose to discuss the methods that are used to determine power conditions without reference to the particular motor or transmission system. In passing, however, it is worth while to remark that any system which requires a rotary converter is to be regarded as a temporary makeshift in most cases. It is a kind of clumsy interloper, to be eliminated as quickly as possible. No doubt it will always have a place in electrical engineering, but there is also no doubt that in the future it will have a small place, indeed, in railroad work. If one might venture a general prophecy it would be, high pressure alternating (3000 to 10,000 volts) overhead trolley for interurban work, and the present 500-volt system for dense city traffic. It would be equally futile to attempt any elaborate comparison of electric locomotives and multiple unit systems. They will probably both find a place, which ultimately will be according to their merits.

It is noticeable that the electrical engineer, when he had advanced

beyond the substitution of electricity for horses, adopted entirely new methods in solving his problems. This was caused by the fundamental difference in power conditions, between the steam and electric systems. The steam unit of locomotion is self contained, converting the energy of the coal into that of the moving train. In the electric system this process of translation is divided. The fuel energy must be converted into electric energy in a power house, this energy must then be transmitted to the car by a conducting system, and then converted into mechanical energy by an electric motor. This means that before construction starts, the capacity of the road, its train service, etc., must be more or less accurately determined. A tentative schedule at least must be laid out, the size of car and its load must be carefully determined, and the alinement and profile of the road must be known. From these the energy required and its distribution must be calculated. Much of this has no correspondence in a steam system. The selection of the size and number of motors has its counterpart in the selection of the locomotive, but the transmission system and the power house have no such correspondent. It is this necessity for predetermination that demands the greatest care in design and caused the invention of the new methods of handling problems. A change in schedule might very easily require the installation of an extra engine in extreme cases, which means, unless conditions are unusually favorable, a wait of some months or a year. An increase in the number or distribution of trains, with or without a change in the size of motors, might have the same effect. To offset these conditions, we hear of one large steam railroad obtaining locomotives at the rate of twelve per week, though it is possible they may have been ordered a year before. This change in schedule, by massing trains at parts of the road for which such loads had not been arranged, might overload the transmission to a breakdown. These are a few of the problems that confront the engineer, and are not mentioned to set up difficulties, but merely to show the difference between the old and the new systems. We have in mind several cases where motive power men responsible for the moving of freight that had become congested, borrowed locomotives from other divisions than their own, where conditions were less strenuous, and sent trains over the line in a practically solid column. In this respect the steam road has a flexibility not possessed by the electric system. This may be assigned as another reason why conservatism has prevailed in advising a change. Certainly no electric system, as ordinarily de-

signed for efficient working, could stand such conditions as those cited above. On the other hand, it is possible that a more careful analysis of individual cases would show that this lack of perfect flexibility is less serious than supposed.

Our problem of the predetermination of power conditions can come from two rather different directions: First, we may have a steam road in operation, on which it is proposed to change the motive power to electricity; and second, we may have to provide the complete motive power equipment for a new project. We shall call these the *Substitution* and the *Project* problems, respectively. In either case, the schedule is known, though subsequent calculation may show that certain changes would be desirable. The alinement and grades are fixed beyond change. It is evident that so far as these civil engineering features are concerned, the determining conditions cannot be greatly different from those which now obtain in steam practice. There is no doubt that single car trains, or any trains in which the motive power is distributed so that a large percentage of the weight is on the drivers, can climb heavier grades than any locomotive outfit. Little advantage can be taken of this, however, for it would seldom be economical. The same reasoning will apply to the decreased rigid wheel base possible in either a locomotive or a train, where the motors can be distributed among the axles, and a flexible connection permitted, and consequently quicker curves. Undoubtedly certain changes in present standards for these matters will be found desirable but time and experience will decide when these are advisable.

There are in general three methods that can be applied to the solution of problems of this kind. The first we may call *The Observation Method.* This involves the use of a dynamometer car and is useful for the *Substitution* problem only, or for the almost impossible cases where the power conditions might be determined after the roadbed is finished. The second is the *Speed-time Method* and is applicable with varying difficulty to either type of problem. The third may be called *The Mean Power Method,* and is the most approximate of the three mentioned. It is also applicable to either type of problem. Before discussing these methods, it may be well to glance at that factor on which, in every method the whole solution depends, *viz.*, the car-motor. In this we shall have no reference to the features of electrical design, but merely to its aspect as a piece of locomotive apparatus.

The modern car-motor is a series-wound, slow-speed machine. It is suspended in various ways from the truck, and geared to the axle by a single reduction system. Double truck cars have either a two or a four motor equipment. The prominent features of this motor are: A tractive effort that varies more or less inversely as the speed, compactness, heavy overload capacity, and durability and reliability under most adverse conditions. Owing to the great variation in its

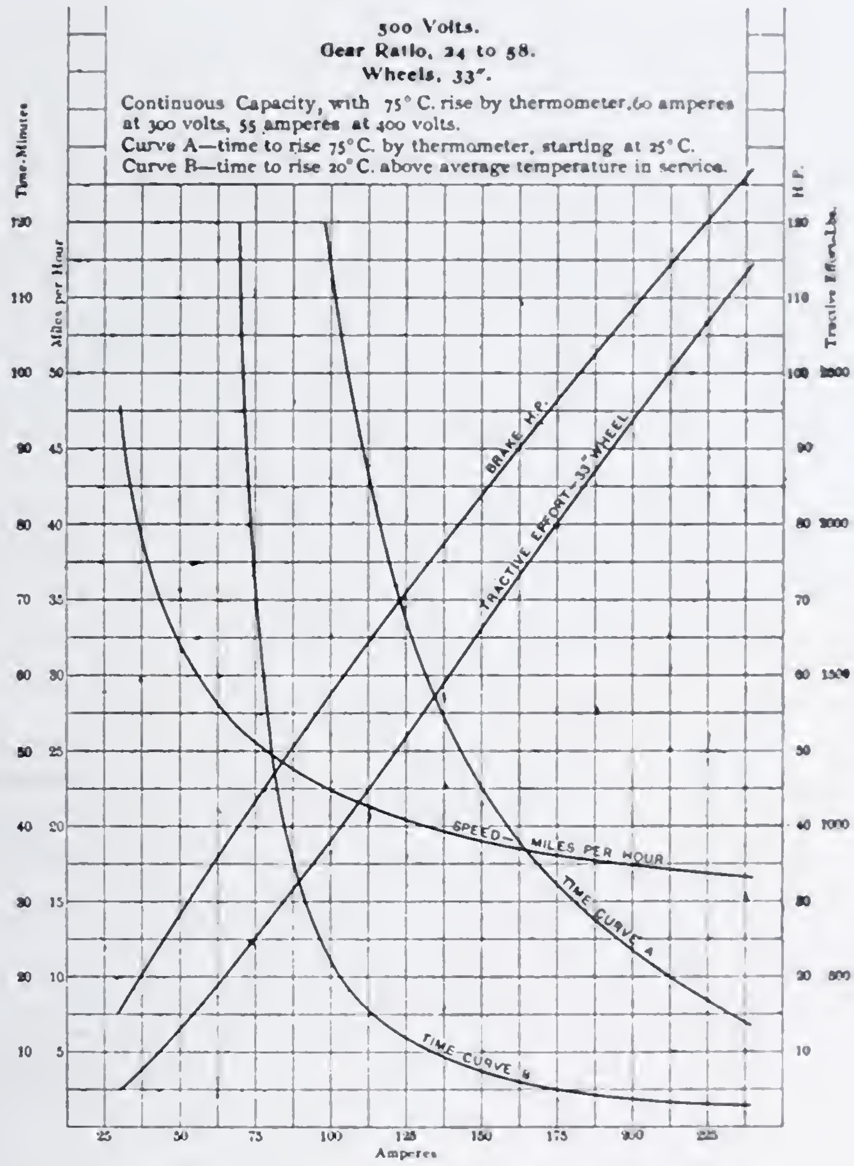


Fig. 1.—Car Motor Characteristics.

load under ordinary conditions it cannot be rated in horse-power for a given time, but must be rated by the uniform current and voltage necessary to produce a certain standard temperature rise, in a given time, over that of the surrounding air. The necessary information about a car-motor is always supplied by the manufacturers in the form of a set of curves as illustrated by figure 1. These curves are drawn for a definite voltage, gear-ratio, and wheel diameter. The

voltage and gear-ratio are subject to considerable variation, but the wheel diameter has been standard for some time. A thirty-three inch wheel is too small, however, for heavy work on account of the lack of room, and wheels of 36 and 42 inches are becoming standard for this work. Curves may be derived easily for other values of these quantities. The speed is almost directly proportional to the voltage, is proportional to the wheel diameter, and inversely proportional to the gear-ratio. The tractive effort is directly proportional to the gear-ratio. The time curves show the temperature rise under the stated conditions. All the companies will supply an efficiency curve if it is desired.

In the choice of a motor for a given service, the first determining factor is the maximum tractive effort required. This must be determined from an examination of the grades, alinement, loads, and schedule. But the same tractive effort may be obtained with different gear-ratios, and it is in the choice of this factor that considerable skill is demanded. A careful consideration must be made of the question of motor temperature. This is a feature that is entirely absent from steam railroad practice. If the locomotive will give the required tractive effort at the required speed, it will do its work. If it is overloaded, even to being stalled, no harm is done. Not so with the car-motor. Continued overloads, or even what is called normal load, if the motor or gear-ratio be improperly chosen, will cause the temperature in the coils to rise to a point at which the insulation chars. Moreover, the bad effect due to high temperature is a gradual one, the charring taking place slowly, and the motor becoming slowly weakened. Finally it breaks down suddenly, and it is hard to convince the proper persons that the accident is not due to some inherent weakness. Nor can this trouble be discovered easily, for it is internal, and temperature inspection is by no means the simplest process in the world—especially the world of car-barns. There is no doubt that with the advent of the electric trunk line, there will be improvement in this respect. We shall probably see the *Motoreer* of the Pennsylvania Limited, some day, examining his field and armature coils after a run with as much solicitation as the present incumbent now caresses his journals.

The Observation Method.

As stated, this requires a dynamometer car, and is useful only when the problem is to substitute electricity for steam without change of

Fig. 2.—P. R. R. Dynamometer Car.

Fig. 3.—I. C. Dynamometer Car.

traffic conditions. Comparatively few roads possess cars of this type. They have been regarded as a kind of expensive luxury. With the advent of electric locomotion, and its necessity for predetermination, we can safely assert that this idea will soon disappear. Through the kindness of the P. R. R., the A. I. E. E., and the "Engineering News," the writer is able to show some views of two of these cars. In figures 2 and 3 are shown the exteriors of the Pennsylvania and Illinois Central cars, respectively. The latter is owned jointly by the I. C. R. R. and

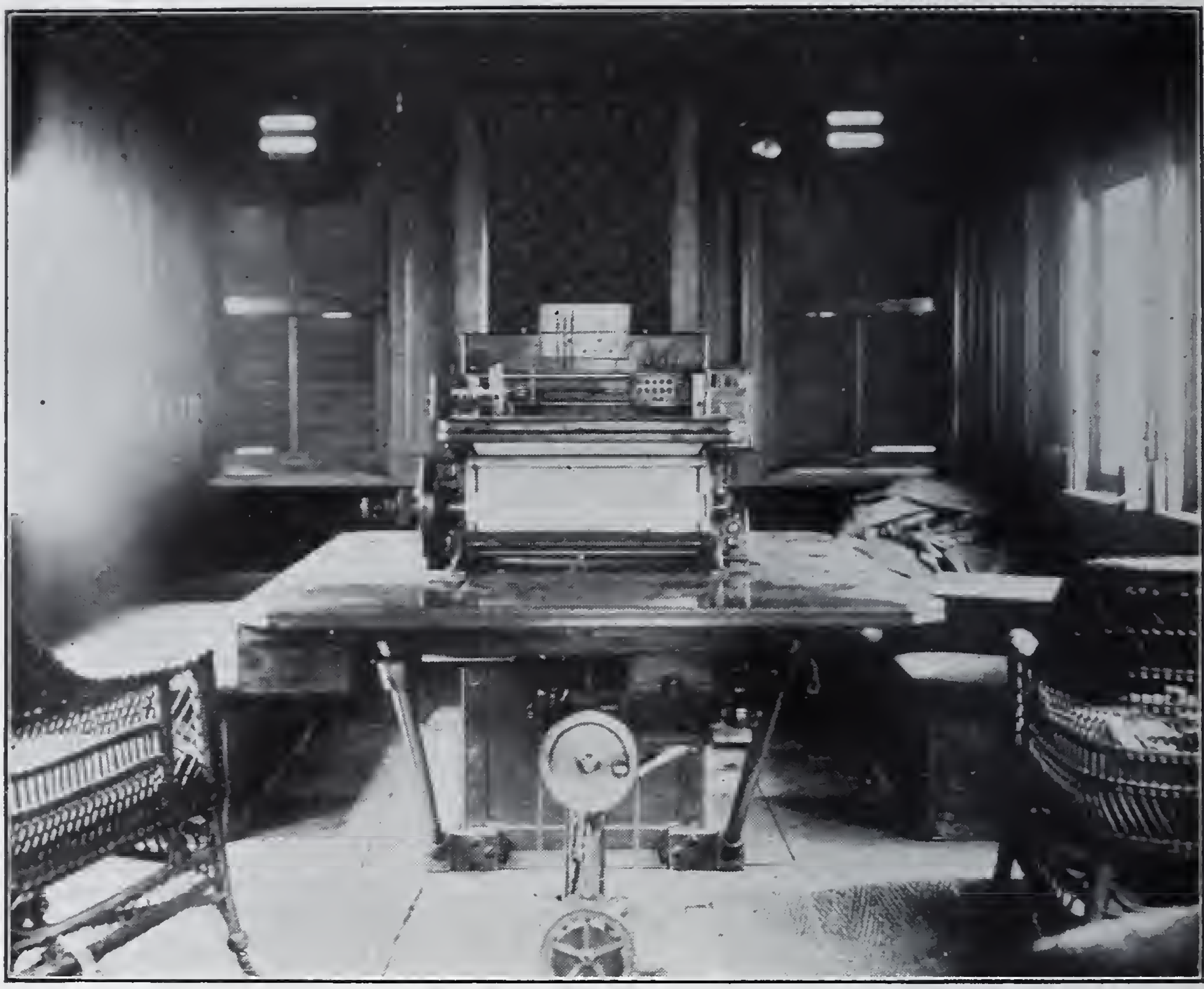


Fig. 4.—Interior P. R. R. Car.

the University of Illinois. The P. R. R. car is small with only four wheels, while the I. C. car has eight. The moving paper mechanism in both cases is connected by suitable gearing with one of the axles, which is not braked. Figure 4 shows the interior of the P. R. R. car with the moving paper table and pens in place. Figure 5 shows the interior of the I. C. car. The dynamometer of the P. R. R. car is made of steel springs entirely, the motion being multiplied by a system of levers, and recorded on the moving paper to a scale of 4000 pounds

to the inch. It is limited to 28,000 pounds. Since it is designed to measure the magnitude of the force only and not its direction, a separate pen must be provided to indicate whether the force is a push or a pull. The following pens making independent records on the one moving paper are provided: (1) A pen operated from the pilot to locate indicator cards; (2) a pen operated from the cab to locate observations made there; (3) a pen operated from various parts of

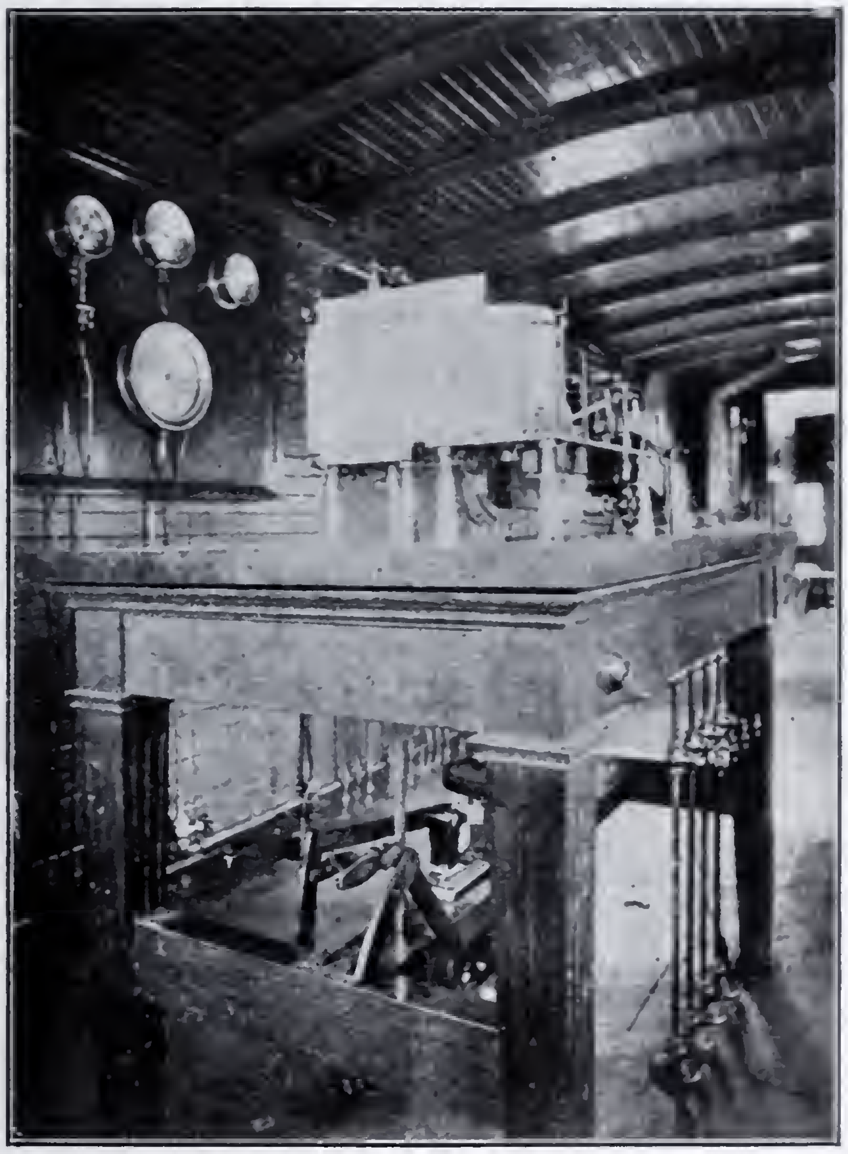


FIG. 5.—INTERIOR OF I. C. CAR.

the car to locate mile posts, points of curve, or any observation made in the car; (4) a pen operated every five seconds by a chronometer; (5) a pen operated by an integrating wheel which integrates the area in square inches, and so the energy in foot-tons; (6) a zero-line pen. There is a speed indicator on the car but no recorder. The paper moves one inch for every 100 feet of track.

Figure 6 shows a diagram of the I. C. dynamometer. It is hydraulic.

supported by springs. Three oil cylinders of different diameters are provided so that it may be used for different average draw-bar pulls. The leakage of the oil past the pistons, since they cannot be tight on account of friction, is compensated for at intervals by a small hand pump. The pressure is recorded by a lever system connected to a Bourdon gauge. This car has a Boyer speed recorder, a location pen, and a zero-line pen.

Figures 7 and 8 show two records given by the P. R. R. car, taken on a freight and on a passenger train, respectively. The chief difference is in the amount of draw-bar pull, and the smoothness of the running. Sufficient information in regard to these records will be found on the sheets. The portion shown represents only a half mile of road.

Figure 9 shows the exterior of the Louisiana Purchase Test Commission car, which was designed by Prof. H. H. Norris, for the measurement of air resistance. The car box rests on ball bearings, on a pressed steel platform car, with stops to prevent excessive motion. The pressure of the wind is measured by the motion of this box, through a system of levers inside the car which forms a delicate dynamometer. Careful arrangements have been made to relieve the box of every stress except those due to wind. It is possible to separate the head and rear resistances from the total. The experiments are being carried on now, but no results have been published yet, though they are expected this summer.

Given such a car in good working order, which means also given men who know how to work it properly, for this is no simple matter, the general method is as follows: First divide all the trains, or rather runs, into classes so that it may not be necessary to use the car with every train on the schedule. Then put the car, behind the locomotive, in a selected train from each class, and draw a curve of draw-bar pull and speed. An examination of these curves will show the size and character of the motor or motors desirable. From the motor characteristic curves, similar to those in figure 1, a power-time curve can be plotted for the run. By combining the power-time curves for the various runs in their proper relation, a power-time curve for the whole system can be plotted. From this the power house may be designed. In order to have a proper distribution of current, that is, to determine the proper size and location of feeders, the road must be divided into sections, and the maximum power, with the time that it must be supplied, obtained for each section. With motors,

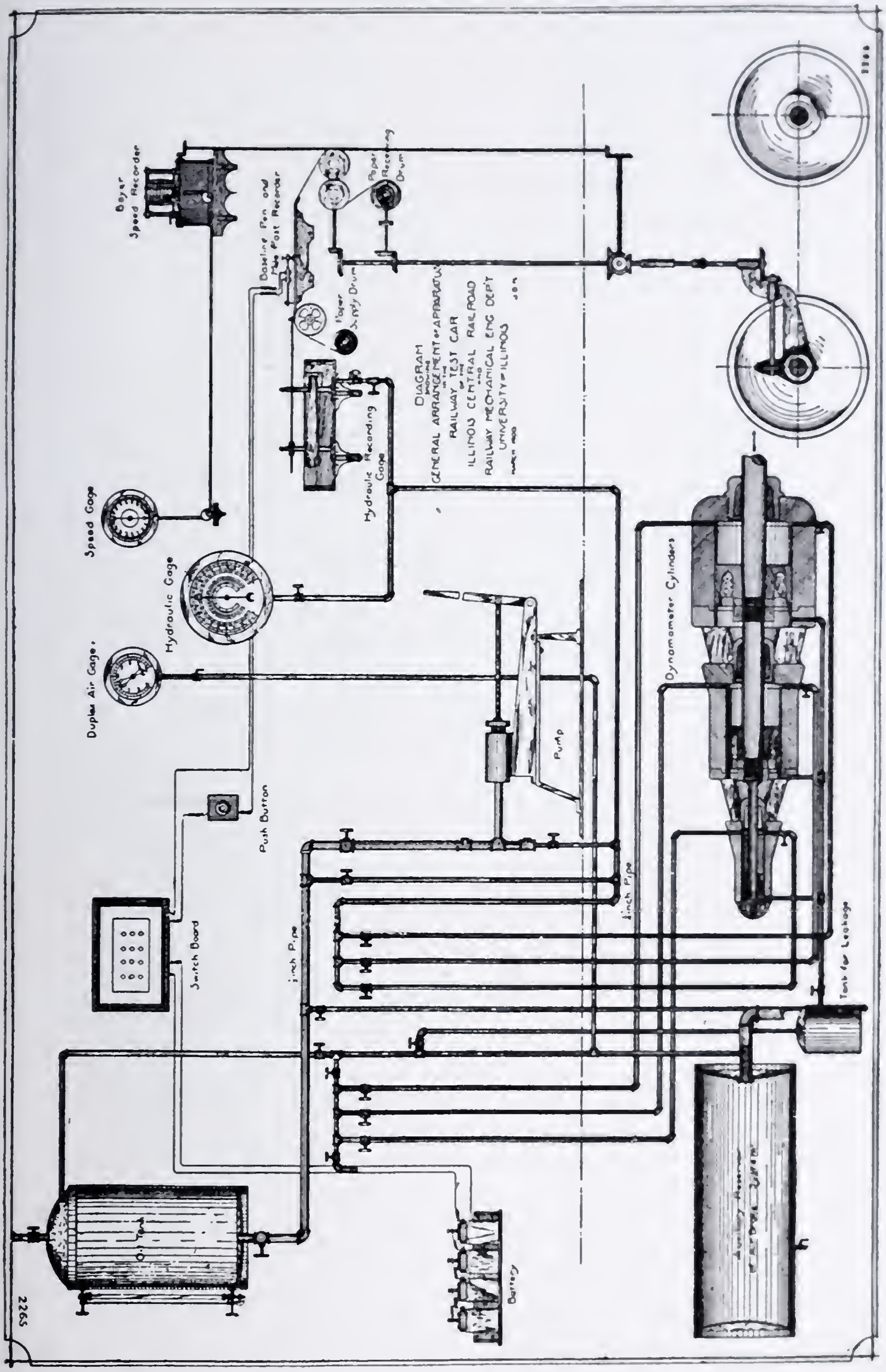


FIG. 6.—DYNAMOMETER SYSTEM OF I. C. CAR.

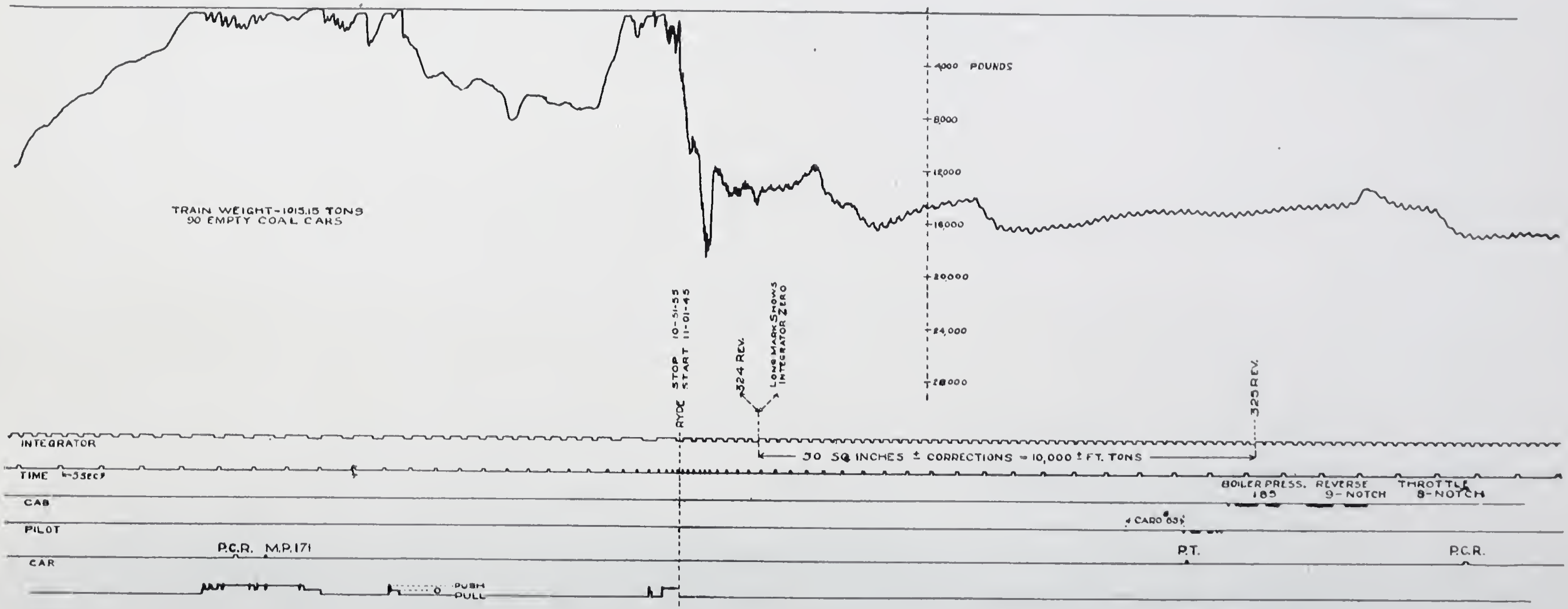
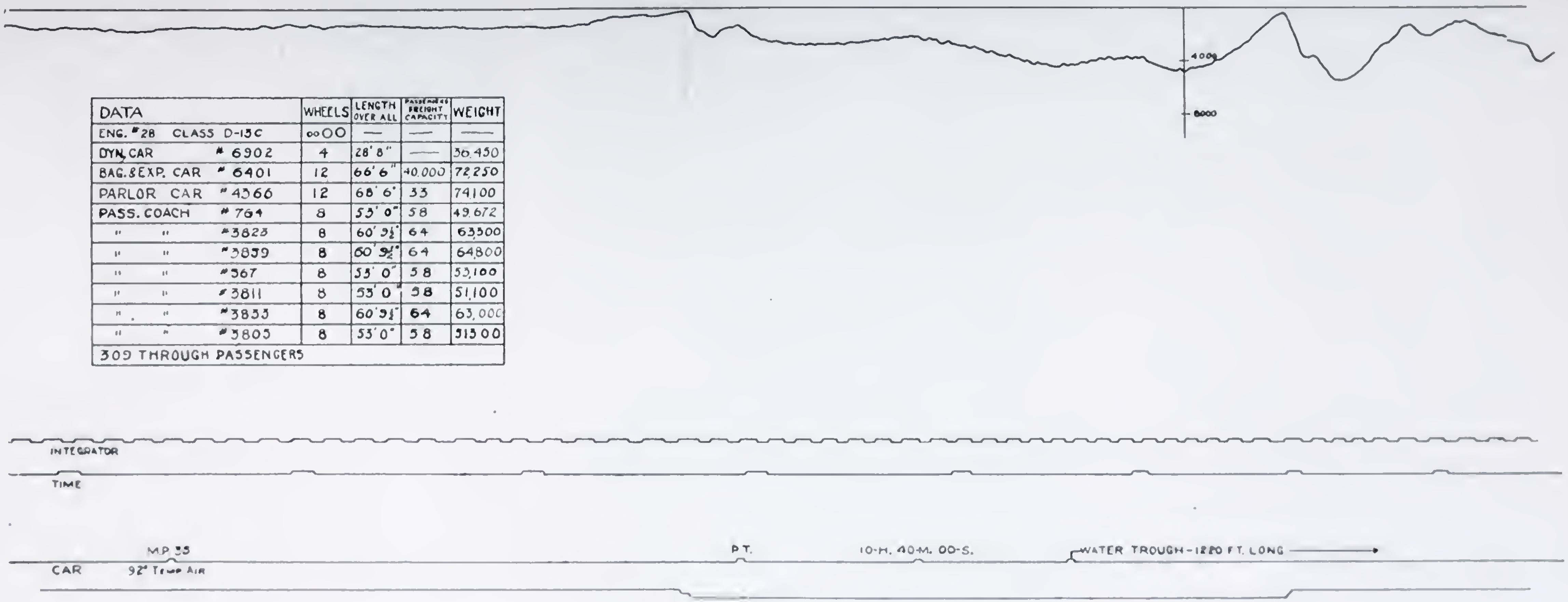


FIG. 7.—FREIGHT TRAIN RECORD.



DATA		WHEELS	LENGTH OVER ALL	PASSENGER OR FREIGHT CAPACITY	WEIGHT
ENG. #28 CLASS D-15C		ooOO	—	—	—
DYN. CAR	# 6902	4	28' 8"	—	36,450
BAG. & EXP. CAR	# 6401	12	66' 6"	40,000	72,250
PARLOR CAR	# 4366	12	68' 6"	33	74,100
PASS. COACH	# 764	8	53' 0"	58	49,672
" "	#3823	8	60' 9½"	64	63,500
" "	#3839	8	60' 9½"	64	64,800
" "	#367	8	53' 0"	58	53,100
" "	#3811	8	53' 0"	58	51,100
" "	#3833	8	60' 9½"	64	63,000
" "	#3805	8	53' 0"	58	51,300
309 THROUGH PASSENGERS					

Fig. 8.—Passenger Train Record.

transmission system, and power house arranged for, the electrical part of the design is finished.

A notable example of the use of this method recently is in connection with the New York Central. Between Mott Haven Junction and New York city there are some 600 trains daily, counting all kinds. When the electrical engineers first attacked the substitution problem here, they tried theoretical calculation first, but soon found that there was too great a lack of data to hope for success, and they had to resort to the Observation Method. The I. C. car was borrowed, and curves obtained substantially as described above. Many rapid

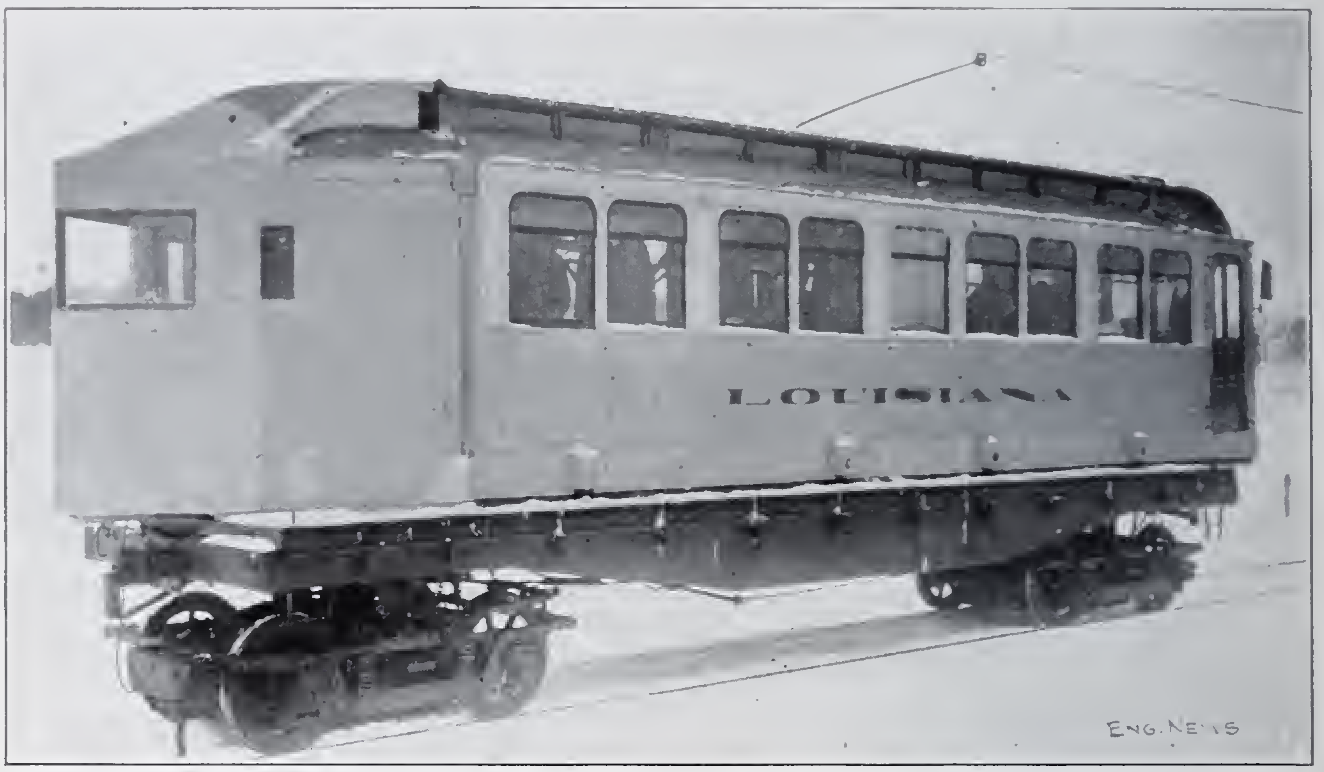


Fig. 9.—Exterior of Exposition Test Car.

calculation diagrams were designed to facilitate the work, consisting as it did of so much detail. That their work was well done is shown by the recent successful tests of the electric locomotive designed for this road.

The Speed-time Method.

This method is applicable to any problem, but particularly so to the *Project* problem. We have the grades and alinement of the road. From a knowledge of the traffic, a schedule and the character of the trains have been determined. By a careful consideration of the fore-

going we determine to start our calculations with an equipment of a certain motor. A set of motor characteristic curves, similar to those in figure 1, is at hand. With this data, we calculate a speed-time curve for every different run in our schedule. With this curve, and the motor current-speed curve, we can plot the current-time curves for the run. The area enclosed between this curve and the base is a measure of the ampere-hours for the run. This value multi-

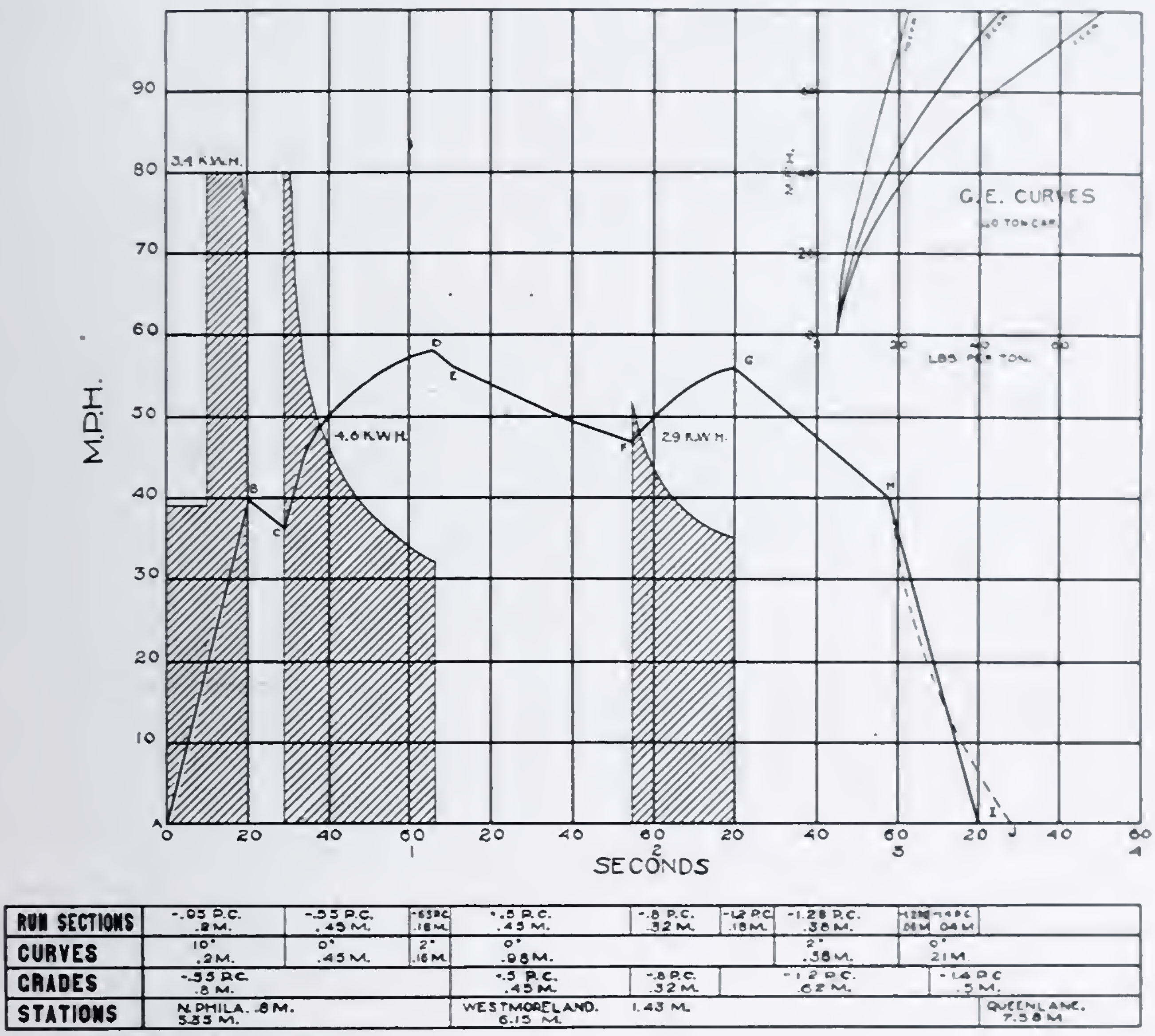


FIG. 10.—SPEED-TIME CURVE.

plied by the line potential will give the energy required for the run, expressed usually in kilowatt hours. As before, by combining the energy curves thus obtained of all the runs in the schedule, we obtain a time-power curve for the system, and make use of this to determine the power-house capacity. The capacity of feeders and other matters of distribution are determined as in the previous method. Frequently a few preliminary or approximate curves will enable us

to determine as to the proper choice that has been made of the motor, gear-ratio, etc. Even the schedule might have to be changed for economic or necessary reasons. These preliminary curves correspond to the preliminary survey in the civil engineering side of the project.

To illustrate the above, the writer has plotted a speed-time curve (figure 10), for a short express run, over a portion of a road very familiar to many Philadelphia riders. The run is made by a car of a total weight of about 55 tons, equipped with four motors, each capable of giving a maximum gross tractive effort of approximately 3000 pounds, with 400 amperes. Beneath the curve will be found the line

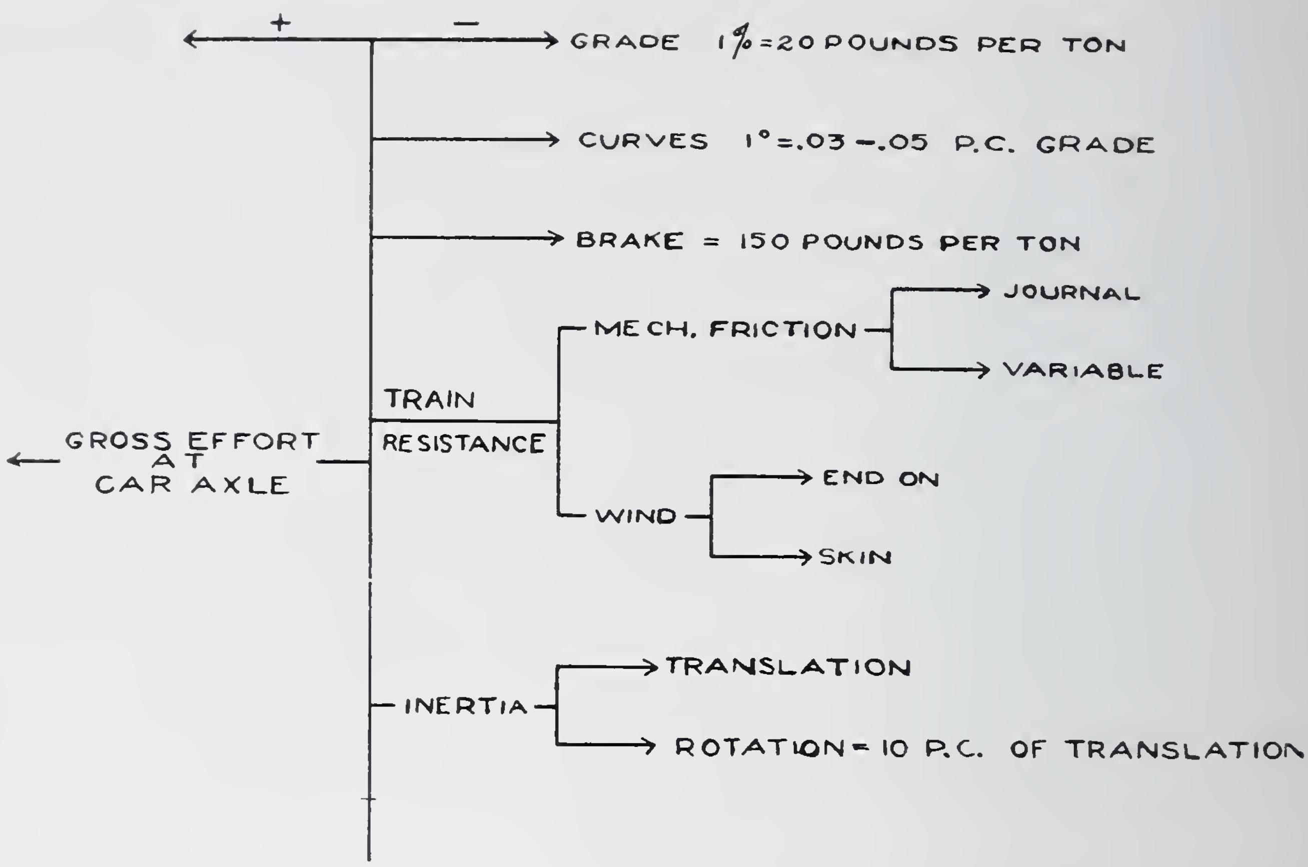


Fig. 11.—Division of Tractive Effort.

data. First, the stations with their terminal distances, and also the intermediate distances; second, the grades with percents and lengths; third, the curves with lengths and degrees, and finally the run sections. These terminate where a stop, change of grade, or change of alinement occurs. In the run sections are marked the lengths and the "equivalent grades." These are calculated by adding to the real grade the resistance value of the curve, measured in terms of grade resistance. The cross-hatched areas are a measure of the energy as explained above. This is the gross energy received by the motor from the line, since we calculate it with line potential. The values attached were

obtained by taking the areas with a planimeter, and reducing them to kilowatt hours. This curve is a fair example of a speed-time curve. It consists of three acceleration parts (AB-CD-FG, figure 10), three drifting parts (BC-DF-GH), and one braked part (HI). The simplest cycle would be accelerate, drift and brake. Sometimes in the most rapid schedules, even the drift is cut out, and the entire stored energy dissipated at the brake. The run occupies 3m., 20s., and has an average speed of 40 miles per hour.

To plot such a curve requires that, under all conditions, we shall be able to state the net tractive effort, that is, the part of the gross effort which is concerned in producing acceleration. It is the gross effort minus all resistances to motion. If P be this effort in pounds per ton, and a the acceleration in miles per hour per second, we have the simple relation:

$$a = .011\ P.$$

Numerous methods have been devised to shorten the labor of obtaining the accelerations at various speeds, and the time points corresponding to these speeds. Many of these are mere cut-and-try graphical methods. There is no convenient analytical method. By far the most expeditious for all kinds of curves is the *Chart Method* devised by Mr. C. O. Mailloux, and presented before the A. I. E. E. in 1902. In the use of any method it will often be found time saving to plot a series of general curves, and interpolate from these. As stated above, to plot these curves the net tractive effort is needed. To obtain this it is necessary to analyze train motion, and get expressions for the various resistances that merely dissipate energy.

In figure 11 will be found a diagram that divides the gross tractive effort into its various parts. A short discussion of each part follows.

Grades.

This resistance is simply the component of the car's weight along the grade. It is perfectly definite as stated. Care should be taken, however, to check grades that have been located for great lengths of time. Railroad men regard grades taken from old location sheets as more or less unreliable.

Curves.

Curve resistance is usually stated as an equivalent grade resistance. This is merely for convenience in calculation. The values given are

somewhat widely separated. They have been obtained largely from steam practice, and probably need modification. Curve resistance, if the curves are properly placed, is a comparatively small part of the whole. With trains of all speeds running on them, curves can be placed only for one speed, and this increases resistance values at other speeds.

Braking.

Very little that is worth much is known quantitatively, though we have learned much through the work of men like Parke. It is common to assume that the braking effort is constant at all speeds. This is incorrect, for the braking curve is never a straight line, and very erratic in its forms. Frequently it is like the dotted line HJ, in figure 10. Owing to the uncertainty, the braking effort is assumed to be 150 pounds per ton, which includes all resistances except grade resistance. This is corrected for, and the net braking effort obtained, which is used in plotting the braking portion of the run.

Train Resistance.

It is here that the motive-power man meets his serious trouble. The electrical engineer has felt the great lack of information, owing to higher speeds, and rapidity of acceleration. It is the great residual of all resistances and errors that are left after subtracting grade and curve resistances. If we attempt to state its sources, we have only two—air and mechanical friction—both of which are almost indeterminate by nature.

Mechanical Friction.

This is caused by: (*a*) Unevenness of the rail, and lack of firmness of the roadbed; (*b*) flange resistance, often excessive, owing to faulty location or maintenance; (*c*) increased flange resistance, owing to side pressure of the wind, as distinct from wind resistance proper; (*d*) journal friction. Motor friction is not included, on acceleration, for the motor curves give the tractive effort at the car axle. On drifting curves, the motor friction must be included, since the energy stored in the car must turn the idle motor. Mechanical friction, while large, can be often greatly reduced by proper maintenance of cars and roadbed. At high speeds it is relatively unimportant, compared with wind resistance.

WIND RESISTANCE.

This is divided into head, rear, and side or skin resistance. These are functions of: (*a*) Relative velocity of train and air; (*b*) shape of car ends, particularly the head end; (*c*) number of cars in train; (*d*) nature of train connections, that is, vestibuled or open; (*d*) area of cross-section of car. The values that have been obtained for the head pressure by whirling boards, cars with specially exposed wind surfaces, drifting cars, etc., have given values ranging from $0.001V^2$ to $0.004V^2$, where V is the velocity of train. What the skin resistance is no one knows, though we expect much from the late Exposition tests, which will be published soon. The writer heard it remarked not long ago that one locomotive engineer said that he had little difficulty in making time against a head wind, but that side wind impeded his train greatly. Many theoretical experiments have been made lately on skin friction, for it is of as much importance to the aeronaut as to the railroad man. It has been found, so far, that it is very similar in its laws to skin friction in wetted surfaces of vessels. It should be borne in mind that wind resistance becomes relatively more important as the weight of the train is reduced, that is, as we approach single car operation. This is shown very clearly by the G. E. curves of train resistance given in figure 10. The increased resistance per ton for shorter trains is due almost wholly to air resistance. These curves are probably as accurate as any up to 60 miles per hour.

Owing to the difficulty of separating the parts of train resistance, most experimenters have chosen to find the total value at various velocities. The results are usually expressed in the shape of a formula. These are as numerous, relatively, as flies in summer. We shall mention two of the simpler ones, and three that aim at accuracy at high speeds:

$$\text{Baldwin, } R = 3 + \frac{V}{6}$$

$$\text{Engineering News, } R = 2 + \frac{V}{4}$$

$$\text{Davis (45-ton car), } R = 5 + .13V + \frac{.0035\ AV^2}{T}\ [1 + .1\ (N-1)]$$

$$\text{Smith, } R = 3 + .167V + .0025\ \frac{A}{T}\ V^2$$

$$\text{Mailloux, } R = \left(\frac{b}{\sqrt{T}} + g\right) + .15V + \frac{.02N + .25}{NT}\ V^2$$

Where

R = resistance in pounds per ton.
V = velocity in miles per hour.
A = cross-section of car in square feet.
T = weight of train in tons.
N = number of cars per ton.
b = constant depending on diameter of wheels and journals (6 to 9).
g = constant depending on condition of track (2 to 5).
n = total number of cars in train.

The trouble with all the above formulas, and the many others like them, is that, derived as they were from special conditions of some sort, they will not answer for general work. The problem is analogous to the famous Kutter formula in hydraulics. Some day when we have sufficient data we shall be able to write a formula, with varying parameters, that can be applied to all cases with reasonable accuracy. As an example of the use of one of these formulas in a special case, namely, the operation of a 45-ton car at 100 miles per hour, it would take some 68 pounds per ton to overcome air resistance alone. Just now, we pick out the particular formula, the data of which was obtained under conditions similar to those of our problem. Our definite knowledge seems to be that with properly shaped cars, train resistance for single cars up to nearly 100 miles per hour, will not greatly exceed 30 pounds per ton, and that the formula, when found, will be of the form:

$$R = A + BV + CV^2$$

Where A is a factor depending chiefly on journal conditions, B is a factor depending chiefly on rail conditions, and C is a function of train weight and formation.

The Mean Power Method.

This is hardly more than a refined guess. It is useful in the very simplest projects only. We know from a very small amount of recorded data, the amount of power required by a car to go over a certain average roadbed. On this scanty basis, estimates have been made as to the amount of power required by roads, and motors selected for the work. The results have more or less accuracy, usually less, depending on the skill of the estimator. In the past it has been responsible for many failures. It is passing out of use.

It will be realized from the above discussion, that this particular field of engineering has had a great development in a short time. The object of all the labor and time spent on it is twofold: First,

to provide means of choosing the most economical equipment and schedule; and second, to predetermine with some degree of accuracy, power conditions, both of generation and distribution, so that construction may go on with no doubt as to the outcome. No mistake should be made relative to the standpoint in this matter. Mere inspection of a power-time curve for a given run does not furnish the final criterion. Power economy does not fix the choice of motors or settle matters of schedule. Far and above everything else is traffic. It must be remembered that cost of power is not the largest expense in railroad work, and that it does not increase at all in proportion to traffic. Therefore we are not after the run which gives the least power, but the one that increases the passenger and tonnage account. Nevertheless, after the schedule has been determined the electrical engineer must see to it that the car makes it with the least possible expense. It should not be forgotten, in this connection, that the matter is as much a matter of operation as design. It is an easy matter to arrange a run with a certain succession of accelerations, drifts, and braking portions, but some scheme must be devised that will hold the man at the controller to this run as arranged. In a measure time points will eliminate this, but he will still be able to waste power by cutting out the drifting portion of the curve.

The striking point in connection with the discussion of this whole problem is the great lack of data. This is not merely so in regard to the particular points discussed in this paper. As average speeds increase, and therefore rapidity of acceleration, especially with frequent stops, many features of train problems become relatively more important. The limit to acceleration is the comfort of the passenger. This is to be remembered particularly in connection with suburban work. A passenger does not complain much of a little jolting at the beginning and end of an hour's run, but the same thing happening every five minutes is likely to be resented. To accomplish both high speed and comfort of passenger, problems must be approached more definitely than they have been frequently in the past. It is rather striking that in connection with the first real substitution problem, one of our largest railroads had to borrow a dynamometer car. Notwithstanding this, motive power men know to a nicety what their locomotives will do. The yard master has his instructions, and loads each engine to a definite amount. If more is to be sent, other trains are made up in the same way, as long as there is a locomotive of the right type in the yard. The criticism has been made that steam

roads and locomotive builders never did, and still have not the facilities for the same kind of elaborate experimental work that has been done by the great electrical companies. This is probably true, but they have not needed the information in the same way that it is needed now. Conditions are different and methods must be different also. The Pennsylvania Railroad is now building a very elaborate dynamometer car of the hydraulic type, and is erecting a very complete testing shop for locomotives.

The fact is, no real progress will be made, from the real engineer's standpoint, until this data is procured. It matters not whether we are considering locomotive or multiple unit control system. For the former a dynamometer car is necessary, and for the latter, a set of recording instruments. Tests must be made from two distinctly different standpoints. First, by means of specially arranged cars, in order to isolate certain factors and measure them. But equally or more important is the second, that is, tests on large numbers of cars in commercial operation, on all kinds of roadbeds, under all kinds of weather conditions. For this purpose special cars, fitted with meters, such as have been used frequently in the past are not just what are needed. We need something in the nature of a table that would occupy a double seat in an ordinary car, containing apparatus to record volts, amperes, speed, and if possible progressive temperatures of the motor. Such a set arranged to be quickly put in circuit, could be shifted from car to car as frequently as desired, and readings taken wherever wanted. This would give a knowledge of operation that will never be obtained in any other way. The cry is now going up for data in central station work, in lighting, everywhere, but nowhere is it needed more than in electric railroad work.

DISCUSSION.

Mr. W. O. Dunbar (Visitor).—The new dynamometer car, of the Pennsylvania Railroad, referred to in the paper, is in process of construction, but will require some time to complete it.

It is not possible to give a brief description which will do full justice. The only way for any one desiring a fair idea is to study the drawing in detail and see the car itself. It will then be possible to appreciate the work that has been accomplished by the mechanical engineer in the designs.

I will attempt, therefore, to give but a general idea of the principles involved, which may prepare any one not already informed what to look for and expect, should he have an opportunity to inspect the car.

The car as a whole is of special design throughout and is carried on two trucks,

each having four wheels of 33 inches diameter. The trucks are of new design, necessitated by the form of construction of the underframe of the car. The main features, however, are three, the dynamometer being on the hydraulic principle:

1st. The drawbar and its attachments to the hydraulic cylinder.

2d. The weighing mechanism and transmission of the pressure to give the necessary movement of the pen, which is to indicate the amount of the pull.

3d. The paper diagram driving mechanism and the connection to the axle of the car.

In this order it may be said that the underframe of the car is completed; being made excessively strong. The central portion of it consists of a heavy steel plate box girder 21 inches deep by 38 inches wide extending 51 feet, the entire length of the car, forming a practically dust-proof and water-tight housing for the drawbar and its attachments.

This drawbar is to be 20½ feet long from the front end of the coupler to the rear end of the hydraulic piston. The piston is 8 inches long by 16¼ inches in diameter, with piston rods at either end 6 inches in diameter, and fits the cylinder with the greatest possible accuracy to work without friction and without packing.

The drawbar, at the coupler end, is made up with a standard automatic coupler and Westinghouse friction draft gear, as in our standard freight cars, but caged in a rectangular, box-like, steel casting, which is open at the front end only and large enough inside to allow free room for the side play of the coupler at the open end and for the cushioning action of the inclosed draft gear. This particular steel casting may be called the coupler cage. The rear end of the coupler is pivoted to the front end of the draft gear to allow the side play referred to. The rear end of the coupler cage is rigidly connected to the drawbar proper, forming a part of it.

The remaining important feature of the drawbar consists of a nest of helical buffer springs confined in a strap under a compression load of 100,000 pounds in such a manner as to form a continuous and rigid portion of the drawbar under all pulls up to 100,000 pounds, the maximum capacity expected to be recorded by the weighing mechanism; but when a pull or push greater than 100,000 pounds is exerted by shock or otherwise, the drawbar stretches or contracts by means of a still further compression of these springs. This is to prevent undue strain being put on the piston and cylinder, which, however, are capable of standing a much heavier load without injury.

From this it will be seen that the drawbar altogether is a pretty massive piece of apparatus. Great pains have been taken to support this drawbar, as a whole, so that for any pull or push it will move practically frictionless.

The coupler cage is supported by six circuitous groups of hardened steel balls, 32 balls in each; two groups beneath, two above and one group on either side, each group giving a bearing over a foot in length. Ten balls of each group, 60 in all, are always in supporting contact with the coupler cage. These balls are each 1¼ inches in diameter and so exactly guided in their races that there is no likelihood of their binding one against the other.

While the coupler has all necessary play within the cage, the cage itself is to be so neatly fitted between the groups of balls that it has practically no side play.

At the other end, as near to the piston as practicable, the drawbar is surrounded and supported by a nest of small balls in a short cylindrical case, which in turn is held in a bushing, so that the nest rolls longitudinally back and forth in its bushing and along the drawbar as the latter moves, but is prevented from creeping along the bar more than 1¼ inches either way by the end walls of the surrounding bushing.

The drawbar is made five inches in diameter for a considerable portion of its length from the point where it connects to the coupler cage to provide ample stiffness; but to further prevent any tendency to sagging, there is located between the 100,000 pound buffer springs and the coupler cage another specially constructed bearing consisting of two rollers, each acting as a support at an angle of 60 degrees with the vertical and turned to an exact radius equal to the distance to the supporting surfaces. These two rollers are pivoted to the drawbar with roller journals and prevented from sliding by being provided with accurately cut teeth, on the outer edge, which mesh with the rack along the edge of the supporting surface.

Buckling from any shock is prevented by cylindrical bushings or guides through which the drawbar passes without friction and at the same time without lost motion. Moreover, when the dynamometer is not in service the coupler cage is locked by blocking specially provided, preventing any load from reaching the drawbar beyond the coupler cage.

The longitudinal motion of this cage, when not locked, is the same as that of the piston and drawbar proper, and is in the direction of the pull along the center line of the car, and for any pull under 100,000 pounds, were there no leakage, would never amount to more than 0.3 of an inch, but in case of shocks or leakage a total motion of 2.8 inches (1.4 inches either way from the central position) is allowed for. This excessive motion will be but temporary in any case, as a leakage pump is to be provided to automatically adjust the piston to its central position.

Since the coupler cage as described has no side play to speak of and so little longitudinal motion, it becomes a comparatively easy matter to completely seal the drawbar as a whole within the box girder of the underframe, to keep out dust and protect the ball bearings from rust, by simply inserting a strip of packing around the outside surface of the coupler cage, between it and the closely surrounding surface of the steel casting which forms the opening in the end of the box girder through which the coupler cage protrudes.

It may be noted here that the box girder described is made deeper for a distance at the point where the piston is located, and also at the 100,000 pound buffer springs, to provide more room for these parts and for getting at them, which will be done from man-holes in the car.

The effective area of the drawbar piston is to be 181.12 square inches. The movement of the dynamometer pull pen at full capacity is to be 10 inches. Thus to get the 10 inches motion, that of the drawbar will be multiplied practically 36 times at the recording cylinder. The pull pen is attached to the end of the piston rod of the recording cylinder, which is 40 inches long inside and $2\frac{7}{32}$ inches in diameter, having the effective area of 5.032 square inches.

The recording piston is 26 inches long over all, and midway of its length consists of a two-wheel carriage 18 inches long, which carries the weight of the pis-

ton. The two carriage wheels are of very nearly the same diameter as the piston itself, the two ends of the piston being each four inches long and the closest possible fit in the cylinder, so as to work without packing and with a minimum of leakage and friction.

The pressure is transmitted from the front or back head of the drawbar piston, according as the force at the drawbar is a pull or a push, to but one end of the recording cylinder, and all oil which leaks past either piston is carried back to the supply and used again without being allowed to offer any back-pressure against the pistons. From this it will be seen that, whether pull or push, the "pull" pen travel is all on one side of the zero or base-line. The indication of a pull or push is to be recorded on the diagram just as in the present car, as described in the paper, but by means of a device which depends on the fact that, in changing from a pull to a push or the reverse, the hydraulic check valves in the drawbar cylinder are not reversed until the drawbar piston has been moved to the other side of its central position by $\frac{1}{16}$ of an inch; that is to say, all pull records will be taken while the drawbar piston is from $\frac{1}{16}$ to $1\frac{3}{16}$ inches forward of its central position, and likewise all push records when at a like distance to the rear of its central position.

The measurement of the amount of pull or push exerted on the drawbar piston is accomplished by means of helical springs, of known calibration, introduced symmetrically around the outside of the recording cylinder to resist the motion of the piston rod of the same. For the full capacity of 100,000 pounds, since the motion is multiplied 36 times, the total resistance to be offered by the helical springs referred to, is one thirty-sixth ($\frac{1}{36}$) part of 100,000 pounds, or 2778 pounds. Now, if we suppose that there are six of these helical springs in the nest, all alike spaced 60 degrees apart around the piston rod, each spring would have a load on it of 463 pounds when there is a load of 100,000 pounds on the drawbar and consequently when the springs are compressed the full 10 inches.

If, now, it is desired to make the capacity but 50,000 pounds for the 10 inches motion, it can be done by removing every other one of the six, leaving three springs spaced 120 degrees apart. Again, if 33,333 pounds is the desired total capacity, it can in like manner be had by removing four of the springs, leaving any two diametrically opposite. And, again, by removing any one pair of springs which are diametrically opposite each other, the four springs remaining will have a capacity for the 10 inches of 66,667 pounds, so that the total capacity of the dynamometer could be made 33,333 pounds, 50,000 pounds, 66,667 pounds, or 100,000 pounds, as desired, or per one inch of ordinate one-tenth of these amounts.

From this it will be clear if, instead of making all the six resistance springs alike, they be made in pairs, but each pair of a selected stiffness, it is possible to have, in all, seven different dynamometer capacities from but three pairs of springs. For instance, if one pair is made to give a total capacity of 10,000 pounds, or 1000 pounds per inch of ordinate, another pair for 30,000 pounds, or 3000 pounds per inch, and the third pair for 60,000 pounds, or 6000 pounds per inch, the possible combinations as above explained will give any of the following seven capacities: 10,000, 30,000, 40,000, 60,000, 70,000, 90,000, and 100,000 pounds, or per inch of ordinate one-tenth of these amounts.

By providing an additional pair or so of these resistances, it is possible to conveniently have any capacity or scale that may be desired, depending

on the nature of the work to be done. Furthermore, it is not absolutely necessary in all cases to entirely remove the springs in changing from one capacity to another, for any one or more of the resistances may be compressed solid while in position, so as not to be included in the resistance to the motion of the recording piston, when pressure is applied to the recording cylinder from the drawbar piston.

The hydraulic apparatus or dynamometer proper, including the method of applying the resistance springs, just described, is the design of Mr. Albert H. Emery, of Stamford, Connecticut, who is also the designer and patentee of the weighing mechanism of the present dynamometer car.

The description which has been given in the paper, of the recording mechanism of the present car, will serve to give a general idea of what will be employed in the new one. The motion, however, will be taken from the axle by a screw gear. Since the axle has a motion in all directions relative to the car body, preventing the use of a fixed shaft, two Hooke's (Universal) joints are included in the line of shafting connecting the screw gear and the mechanism to be driven. These joints, as well as the shaft, are made of a new design, with a view to insuring that they will run in perfect balance at high speeds.

In addition to the recording pens mentioned in the paper, there will be one to lay off a mark every 1000 feet traveled; by counting the number of spaces thus laid off, the distance between any two points located, or the total distance run, can be promptly determined from the diagram within a small fraction of one per cent. Another advantage of this automatic distance spacer is that it provides a means for correction if the paper shrinks or as the wheels on the axle from which the motion is taken wear.

There will also be one spare pen. With the datum pen and pull pen there will be, in all, ten recording pens.

The travel of the paper will be the same as in the present car—52.8 inches per mile, or one inch per 100 feet. The width of the paper diagram has been increased from $14\frac{3}{4}$ inches to 18 inches, mainly because of the greater travel of the pull pen, due to the greater capacity of the car. In fact, it is because the 28,000 pounds capacity of the present car, sufficient twenty years ago, is only 28 per cent. of the capacity thought necessary to provide for today that the new car is being built.

Descriptions with drawings which have been published recently by the "Railway Age," "Railroad Gazette," and "American Engineer and Railroad Journal," of the locomotive testing plant exhibited by the Pennsylvania Railroad at the St. Louis Exposition, will be found valuable in this connection to those interested, as the recording mechanisms in the two cases are very similar.

The car will be lighted by electricity by means of a 5″ × 6″ De La Vergne Machine Company vertical oil engine with direct connected dynamos, in connection with a storage battery, which will also be the means of operating the leakage pump and the eight electric circuits to the dynamometer pens. There will also be sleeping accommodations for eight men, with some other conveniences, including room for a kitchen, but no provision as yet for any cook.

E. P. Coles.—At the risk of calling attention to a few facts that most of us are already familiar with, I presume it might be of interest to speak of one or two features that are essentially quite different in the ordinary trolley cars as we know them, and this heavy traction work.

On the ordinary trolley car, to begin with, the power is taken from the overhead wire by the small trolley wheel. Our interurban cars, in many instances, have already reached the point where it is very difficult to take sufficient power from the wire by that means; the trolley wheels have been quite a source of trouble, and it would be absolutely out of the question to take the power for a heavy train through a single overhead trolley in that way. Mr. McClellan has called our attention to the difficulties that we would run into if we should try to use more than one trolley, so there is no solution to be looked for in that direction on the heaviest trains that are now being operated by electricity. On the elevated and the underground roads in New York the third rail system is used. Of course, that has much wider limits, because the sliding shoe on the third rail gives less trouble than the trolley wheel, and it is not objectionable, therefore, to have a number of these shoes,—one or two per car, for example. When we get into high-tension work on the trolley, then the amount of current to be handled will become proportionately less as the voltage increases, and this will enable us to take very much more power from an overhead trolley line than we can now take by using the 500-volt direct current.

There is another point which limits the amount of power that we can conveniently handle, and that is the controller as used on the present cars, where all the current comes into the controller proper. When we get into the running of heavy trains it would, of course, be practically impossible to build a controller large enough to give sufficient areas of contacts to handle the current and to allow for the very heavy cables used to be led into this controller. To obviate this difficulty, several methods of train control have been put into use, one of which consists of a single small controller, known as the master controller, which is not more than one-fourth the size of the ordinary controller on our city trolley cars. The only current that passes through this master controller is that which actuates the magnets, which are called "plunkers," and are mounted on the bottoms of the various cars in the train. It does not make any difference whether there be a single car or a number of the cars in the train, all equipped with these plunkers, a single controller from any car in the train can operate them all, and the current for the motors passes through these plunker magnets, or the contacts which are controlled by these magnets, but not through the master controller.

There is another point that we must consider when we begin to put very large motors on cars. On the ordinary trolley car the motor is hung entirely from the car axle; that is, the body of the motor itself is hung from the axle, and, of course, any motion or any jolting of the car axle is imparted to the whole motor and it all moves together. On some of the larger motors that have been built, as, for example, the ones on the New York Central locomotive, the armature of the motor is on the car axle, whereas the body of the motor, the pole-pieces and the field coils, are hung from the car body itself. They have motions independent of each other, and in order to prevent any striking of the pole-pieces on the armature the air gap is made much larger than on the ordinary trolley motors, and the pole faces are so arranged that there is a very slight amount of concavity on them. On the New York Central locomotive, for example, the motor case can move vertically as much as 4 inches, independently of the armature, without causing the armature to strike on the pole-pieces.

H. A. Foster.—I have made one or two notes regarding Mr. McClellan's paper. He speaks of reasons for being rather conservative in the re-equipping of large steam roads with electricity, and I think that he is entirely right, but I think we might qualify that particular statement a little in this way: If these equipments are to be largely for passenger conditions, that is, for the short-haul business, etc., we could consider other reasons for changing than economy in power or fuel, for the reason that it has been found by, I may say, in some cases, sad experience, that the increase in traffic has been so much as to show that the predetermined calculations have been too small and it has been found difficult to re-arrange them afterward.

Mr. McClellan speaks in his paper, in referring to the determination of the power required, of making an experienced guess; he speaks also of its being very crude, etc., and I think I am right in saying that probably seven-eighths have guessed too little on the power, because the promoter did not want to pay for as much power as the engineer deemed necessary. I think we are fortunate in one thing, and that is in having the experience of all the locomotive designers and engineers to work upon in connection with electrical locomotives. Few inexperienced engineers would otherwise ever get things strong enough to bump up against a freight train and not break something. As to the matter of overcoming the question of high voltage, insulation, and so forth, that is a matter that we cannot very well dispose of. We must have a high voltage, simply because we cannot take the current off the wire without it. The question is going to be largely how to handle it. As we found it at first rather difficult to insulate at 500 volts, I think it will be found still more difficult to insulate against a potential of 1000 volts, and still more for 3000, 6000, or 10,000 volts. As far as danger to life is concerned, it has been found that 3000 volts will kill a man just as dead as 10,000 volts will. Now, the question is to get insulation enough, for with any of these, 2500 or 3000 volts we reach the danger-point,—but we must insulate things so that people will not be afraid to ride on the cars. Mr. McClellan speaks also of the motorman destroying all our calculations. Mr. Hewitt read a paper here a few years ago about some trials that were made on some long runs in Philadelphia, where a watt-meter was placed upon a car which was run over a certain line for perhaps a week, trying each motorman, making a record of him, noting the number of passengers, time taken, etc., and I think they found differences in power consumption of upward of 45 per cent. due wholly to the personality of the motorman himself. Therefore it is a little difficult to calculate on just how much power any motorman will take. For this reason, there have been introduced within the last year automatic accelerators. They are being used in some parts of the subway system in New York, where all the motorman has to do is to turn the crank clear around, and the accelerator moves the train up gradually and evenly.

It is possible that some of our locomotive friends may think that these speed time curve determinations are highly theoretical and very pretty, and that they take a lot of time; and they may possibly question their accuracy somewhat. I have seen curves of that kind that were predetermined for a line of road 7000 feet long, accurately measured with all the different grades, carefully surveyed, etc., and the speed time curve built up from the motor characteristics furnished by the manufacturer overlaid the curve developed by an automatic machine

on the car equipped for the purpose of running over this line, with the predetermined loads, etc., so closely that you could hardly tell them apart. So I think there is no question of accuracy of the results. It has been found, so far, to be the only method that we can use in order to predeternine in a new road just what power will be required.

CARL HERING.—Mr. Foster has already mentioned a number of points that I wanted to call attention to. Mr. McClellan speaks of working according to a given schedule as a basis, and shows how accurately one can then make the calculations. But it seems to me that the great difficulty lies in making out this original schedule, because the road itself, after it exists, will change the whole schedule that one started out with. I once heard a very prominent electrical railroad engineer say that he made a calculation as to whether it would pay to construct a certain road near New York, and found that it would not pay because the present traffic did not warrant it. Now this method seems to me to be a great mistake, because we all know very well that the introduction of a new road will develop a new and sometimes very large traffic, like in this city, for instance. As Mr. Foster has already stated, the traffic often increases so very much that our original calculations, based on existing conditions, are entirely wrong. Who would have thought a dozen years ago, for instance, that such an enormous traffic would have developed between here and Willow Grove? Before that line was constructed there was scarcely any traffic, and now there are days when I believe there are ten or twenty thousand people, or even more, carried out there. I therefore do not think it is often possible to have at the start the accurate working schedule that Mr. McClellan speaks of in his paper; and accurately made deductions based on grossly inaccurate assumptions cannot give accurate results. He says, for instance, that the schedule "is known," but very often I think we will find that it is not known.

Mr. McClellan speaks of the system of rotary transformers as a "temporary makeshift." This, however, is the system which is most largely in use at the present time. We hope it may be only temporary, but a thing that has been used largely and successfully a great many years, can hardly be called a "makeshift."

In connection with the energy required to operate a road, I call attention to the excellent scheme resorted to in the new London underground road; it diminishes the amount of power required quite considerably. On this road, which is from 50 to 70 feet underground, the grades are so established that the stations are high, while between stations the road runs down and up again to the next station, like the dips on the children's toboggan railways. When the car starts it always goes down-grade first, and therefore has the grade to assist it in accelerating; and after it has drifted and has come near to its next stop, it mounts the grade, and in that way the power which has been stored up and generally goes to waste in the brakes is made use of. That is possible, of course, only where you can establish your own grade, as in an underground road. In our city streets the reverse conditions always exist, the highest point being between two streets instead of at the crossings, so that the cars always have to start and accelerate on an up-grade, and brake on a down-grade, which is just the reverse of what it ought to be. In laying out new cities it might be worth while to consider the question of reversing the ordinary custom, and have the crossings higher than the points between the streets.

Mr. McClellan has perhaps given the impression that very accurate figuring is more *necessary* for electrical engineers, for establishing their roads. I do not think that that is quite correct. It is not that electrical engineers *need* all this accurate data; but it is because they *can* work with far greater accuracy, that they can make use of such data, therefore the data is desirable. With steam engineers such accuracy is not necessary, because they cannot work as accurately. They simply build their locomotives much larger than is necessary, and that is all that is required. If they do not need the power, they simply put in a little less coal. They could not work so accurately even if they had the data.

Charles Hewitt.—As I understand Mr. McClellan's paper, he discusses the method one must pursue in solving the problem of equipping a heavy traction road with electricity. He has brought before us the prominent lack of certain data and he has set before us the figures and data that we can work on, and the things which should be determined accurately for future work. It is an old saying that "history repeats itself," and it seemed to me as I listened to Mr. McClellan tonight that we are repeating what we first went through in abandoning the old horse-cars. Years ago—about 1887 or a little earlier—they were experimenting abroad and determining certain things, trying to get data on which to equip cars for light transportation; while in this country Sprague and others went to work and got something running, and began carrying passengers, and finally we have a very large development here now, and know pretty well what can be done in that line. The same thing is going ahead in this country today in heavy traction work. Abroad they are spending a great deal of money in determining the data which we now lack. Experiments are being carried on near Zurich and other places in Germany with high-tension lines, not only determining the amount of power required, but almost every conceivable design of insulator and collector is being tried, and they are determining various other data that enter into the problem. In the meantime, in this country the New York Central and the Baltimore and Ohio Railroads have gone ahead and have built very large locomotives, and probably by the time they reach the end of their experiments in Europe roads will be running in this country. That is in a few words the situation as it stands today. Nobody yet has attacked the long-distance trunk line problem except on paper, and before that is undertaken the necessary data will have to be determined. I was asked this evening whether I candidly and honestly looked forward to the day when the trunk line would be electrically equipped. I am free to say that I do not intend to be a prophet, but he would be a very unwise and a very foolish man who would attempt to dispute the fact that some day the trunk line will be electrically equipped. We have seen more wonderful things happen in our short lives, and I expect to see it, if I live a few years longer. Just what form it will take, and what details, and what voltage it will take, we may not know at the present time, but I certainly look forward to it.

Mr. Trautwine.—In Fig. 10 the speed curve shows, between points 0 and B (0–20 seconds), a uniformly increasing velocity from 0 up to 40 miles per hour; from B to C (20–30 seconds), a velocity uniformly decreasing to about 36 miles per hour. From C (30 seconds to about 34 seconds) the velocity appears to increase uniformly to about 46 miles per hour, and from that point to D (65 seconds) the velocity increases, but with a diminishing acceleration, to about 57 miles per hour.

From D to E (65–70 seconds) the velocity diminishes uniformly to about 55 miles per hour, and from E to F (70–115 seconds) it diminishes uniformly, but at a less rate, to about 47 miles per hour.

It then again increases, with a diminishing acceleration, from F to G (115–140 seconds) to 55 miles per hour.

During this same time there were three periods (represented by the three shaded areas) during which work was expended and velocity increased.

In the second of these shaded areas, beginning at the thirtieth second, we have a short period during which the expenditure of work was uniform, and a correspondingly uniform acceleration, beginning at the point C, but in the remainder of that area, and in the third shaded area, the curved upper boundary of the shaded area shows a diminution in work done, corresponding to the diminution of acceleration shown by the speed curve.

All this is as we should expect to find it.

But in the first of the three shaded areas, although the speed curve shows a uniform acceleration, from 0 velocity to 40 miles per hour, between points 0 and B (0–20 seconds), corresponding to which we should expect to find a uniform expenditure of work, we find, on the contrary, for the first ten seconds, only half the expenditure of work which we find in the remaining ten seconds covered by that area.

It would seem, therefore, that, if the shaded area representing work done, is correct, the speed curve, for the first twenty seconds, should show two straight lines instead of one, the first one covering the first ten seconds, and showing a lower rate of acceleration than the second one, covering the tenth to twentieth seconds.

Mr. McClellan.—Well, that is due to the method of car control. Car motors are always a double equipment of either one or two pairs. When the car is started, these motors are always two in series, with a certain amount of resistance in series. As the car speeds up, this resistance is theoretically cut out so as to keep the current at some constant value, which means constant torque. When this resistance is all out, the motors are thrown in parallel, with the resistance all, or in part, in circuit again. This resistance is again gradually cut out so as to keep the current at the one constant value. Until this is all out we have constant torque, and this is represented on the curve by the line A B. Now, as there is no more resistance to be cut out, the further increase in counter electromotive force causes the current to decrease to a much lower value, giving a constantly decreasing torque.

The point raised is therefore easily explained. The energy curve represents the energy given to the motor system of the car. It is only when all the resistance is cut out that the motors receive all this energy. It should be explained that this energy curve is an ideal one, and could only be obtained if the car were supplied with a water rheostat, in which the resistance could be cut out without jumps. The actual energy curve approximates this curve more or less closely, according to the adjustment of the rheostats. To sum up, throughout the straight line portion of the speed time curve, the current per motor, and therefore the torque, is constant. If all retarding forces are constant, this will give uniform acceleration. This does not appear on the energy curve because the rheostats are taking part of the energy supplied.

Mr. Trautwine.—The author remarks: "The trouble with all the above

formulas, and the many others like them, is that, derived as they were from special conditions of some sort, they will not answer for general work. The problem is analogous to the famous Kutter formula in hydraulics. Some day when we have sufficient data we shall be able to write a formula, with varying parameters, that can be applied to all cases with reasonable accuracy."

In this connection, I beg to observe that, when Mr. Rudolph Hering and I made, some eighteen years ago, our translation of Ganguillet and Kutter's work describing the evolution of their celebrated formula, Mr. Hering, with a painstaking perseverance characteristic of the German nation in general and of the Hering family in particular, devoted himself to the preparation of a table covering 90 pages and containing all the data then obtainable, facilitating the determination of the coefficient "n" of roughness.

With this table before him, the engineer cannot complain of insufficient data for the determination of that coefficient; and, with the diagram accompanying our translation, the finding of the velocity, etc., for any given case, becomes a very simple matter.

MR. McCLELLAN.—The speaker is acquainted with the very valuable work to which reference has been made—indeed, what engineer is not who has to do any hydraulic work? Nevertheless there is still some discussion about the correct values of the coefficients, under certain circumstances, and as to the agreement of calculated results with observed ones. Perhaps, however, it would be more accurate to say that the situation is analogous to that which obtained in earlier days of the Kutter formula. There is one important difference that should be noticed. The Kutter formula is for the coefficient *c* in the Chezy formula. The latter is fundamentally theoretical, the coefficient of roughness being calculated from the empirical Kutter formula. Our train resistance formulas, however, are wholly empirical, so far.

It would be interesting to discuss tonight the difference between hydraulic dynamometers and spring dynamometers, as it is a very interesting problem; the whole trouble is the friction. But there is not time for that now. With reference to the point which Mr. Coles brought up, it is an extremely important one, though I did not say much about it in the paper. A car such as we have in mind here might require to take as much as 2000 amperes through one of those little trolley wheels. Now, if you will think of getting 2000 amperes through a trolley wheel, you will appreciate what the result would be. In fact, the third rail, as Mr. Coles intimated, was necessary before this heavy traction work could be done at all. The use of high voltage on the third rail is entirely out of the question. I think, therefore, we shall certainly have an overhead or side trolley to handle this high voltage. In connection with the matter of predetermination, I agree with what one of the speakers said, on the question of guessing too small. I had occasion to deal with this on three different stations, and the only thing to be done was to put on an extra engine and some more generators.

Automatic accelerators are good devices, but they only get the car started properly. The motorman still may take it off when he pleases, which is usually somewhere in the middle of the coasting curve.

In regard to the dipping of the street at the center, for traction purposes, I think the sanitary engineer would have an objection or two to this plan. There is no doubt that this plan could often be adopted to advantage in subway work.

Too much stress cannot be laid on the fact that a high voltage is necessary

for much of our future railroad work if it is to be done electrically at all. That is, it is a *sine qua non*, and not a question of advisability.

A number of points have been raised with regard to accuracy, use, and feasibility of these methods. First, with regard to the schedule. When a road is to be designed, an estimation of the probable traffic and a schedule of some sort is necessary. To be sure, the schedule is always more or less tentative. To make an estimation of the future traffic is always difficult. In the past it has been done either by a promoter, who usually sees double, or by an electrical engineer, who is inexperienced. Seldom indeed has a traffic expert, of the kind to be found only with the great railroad systems, had the problem to solve. Nevertheless experience is gained very quickly in these factors, and our knowledge is much more definite in this connection than it was even a year ago. In the instance cited by one of the speakers—Willow Grove—we have a good example. The promoters in this case did see ahead more or less correctly, as is evidenced by the money originally put into the project. It was not the building of the trolley line itself, but the park and Sousa's band at the other end. What is not so easily estimated is what might be called legitimate traffic or necessary transportation. What we need, and what we shall have in a comparatively short time, is a man who has studied the traffic situation, and can foresee. The problem is likely to be more and more removed from the electrical engineer proper and handed to this traffic expert. One of the largest engineering firms in the country now has a distinct department devoted to this part of the work.

The electrical problem is not capable of any greater accuracy than the steam problem. The locomotive designer can calculate just as closely, if he will, as the electrical designer. But his system has not demanded such methods, and consequently he has not developed them. That within a year or two he has changed his tactics is evident to any one who has studied the situation.

The criticism that these methods are rather finely drawn and theroretical is not tenable. The story of the substitution of electricity for horses on our street-car systems is notorious for its lack of scientific engineering. No engineer wants history to repeat itself in this way. It was an accompaniment of the enormous amount of work that had to be done in a short time. The motor itself as well as the system had to be designed. We are in a much better position now to do things in an engineering way, and we should. Moreover, the former problems were lilliputian compared with our present ones.

The important point to be realized is that we cannot go on in the old way. Our modern high speeds, quick accelerations, rapid braking, and frequent stops, demand the most careful consideration of every factor that enters into the result. It is not a question of getting the cars over the road at some average speed, as it was in the early days of street railroading, but to do this in a certain specified way under most complex conditions. Experimenting is absolutely necessary, and we can only hope that it will be done rationally, each change with a particular end in view, and not with the desire to see what will happen. Moreover, Europe is not doing the work for us, in this case, as was intimated. Data we must have or we cannot possibly succeed, and it is fortunate that this is realized very keenly by those who are working at the problems now. It is a question, for example, if any one knows within 100 per cent. what the drawbar pull is at 60 miles per hour under various conditions. It does not seem as if we were drawing very fine lines in asking for something more accurate than this.

Paper No. 1010.

STEREOSCOPIC VISION APPLIED TO SURVEYING.

E. F. NORTHRUP.

Read May 6, 1905.

Last November it was my privilege to meet Dr. Czapski, who is the technical director of the Carl Zeiss works at Jena, and to learn from him of the intensely interesting developments in optics that this noted house has recently been making. Of several strikingly new instruments described, the two that especially interested me are the "Telemeter" and the "Stereocomparator." It is of these that I will give you a very brief description.

Both these instruments make use of, and apply in many useful ways, the power or principle of stereoscopic vision. Few persons who have not given the subject special study realize the remarkable features, the usefulness and power of making accurate measurement, of binocular or stereoscopic vision. If two photographs of an object are taken from slightly different points of view, the two pictures obtained are sufficiently unlike, so that, if by any optical device, it is attempted to blend them together, by superposition or otherwise, the result can only be a blurred and confused image. But put these two unlike photographs in a stereoscope, or any device by which the right eye sees only the one view and the left eye sees only the other, and instantly the two unlike views blend together in the brain, giving the sensation of a clear image, in outline slightly different from either component view, and possessing the additional property of depth or relief. If two diagrams are drawn, one consisting of a circle with a black dot in its center, and the other like it except that the dot is placed slightly out of the center of the circle, and these two diagrams be combined in a stereoscope, it will be observed that in the combined image the dot will appear above or below the plane of the circle. In general, the principle is found to hold in stereoscopic vision, that when two similar views are stereoscopically combined, all relative lateral displacements of objects in the two views in a line joining the oculars produce the physiologic sensation of difference in depth of these objects. Thus, if one view is that of the starry firmament taken at one hour, and the other view is of the same part of the firmament but taken at a later

hour after a planet has had time to move slightly relatively to the background of the stars, these two views will combine in a stereoscope, and the image of the planet will appear to stand out in front of and away from the background of the firmament of stars. Surely such a remarkable power of the brain which can combine in its sensorium two unlike images and give a third different from either, must appear quite inexplicable, and as being a gift of nature which may truly be called a sixth sense.

In the telemeter we have a binocular telescope which measures the distance, up to several thousand feet, of any object that comes in the field of view. To accomplish this an ingenious application is made of the principle that lateral displacement in the line joining the eyes of an object in one of two stereoscopic views, produces in the stereoscopic image an apparent displacement in depth of the object so displaced. In each of the eye-pieces of the binocular combination at the plane where the two images of the landscape are formed are two small circles ruled on glass. These two circles appear as one when looking through the binocular glass. By means of a micrometer screw adjustment, the circle in the right-eye tube can be slightly displaced in the line joining the eye-pieces of the telescope. As this displacement is made the little circle appears to move off into space. Its position in space can be perfectly controlled by the screw. To determine, then, the distance to any object in the landscape, it is only necessary to look at it through the binocular telescope and turn the micrometer screw until the ring appears to hang just over the top of the object, and then read off the distance in meters on a scale attached to the controlling screw. Such is the Carl Zeiss telemeter. It is made up in various sizes and adapted to work requiring more or less accuracy. In the largest size, in which by a simple optical device the effective distance between the eyes is increased to about three meters, as much as 3000 meters can be determined to a precision amounting to 4 per cent., and smaller distances to far greater accuracy. The uses of such an instrument are obvious: such as, finding the range for guns in war or in hunting with a rifle, in rapidly making a quick and preliminary survey of a rough country or a coast-line as a boat moves along it, estimating the distance of objects over water, and many other purposes of use and pleasure. Dr. Czapski showed me a small Zeiss field-glass fitted with the telemeter attachment, and I could, with great precision, ease, and rapidity, determine the distance of any object within a distance of 300 to 500 meters. I was impressed with the

great usefulness which I believe it would have in the hands of surveyors for all kinds of preliminary work. Objects of uncertain outline, as a column of smoke, can be located in reference to distance, in the horizontal or vertical direction, as well as sharply outlined objects, hence the telemeter should prove of use in determining the height of clouds, mists, etc.

But valuable and interesting as is the Zeiss telemeter, the marvel of this optical work is the stereocomparator. This instrument, while embodying in effect all the principles of the telemeter, is designed to make surveys of photographs of a landscape in a manner similar to that which is done with the telemeter on an actual landscape.

The instrument, briefly described, is a very large stereoscope adapted to viewing in detail with considerable magnification or as a whole two photographic positives 13 by 18 centimeters each. By means of lenses and mirrors the effective distance between the eyes is increased to 18 or more centimeters. The frame of the instrument has adjustments for moving the two plates being viewed together in any direction in a plane, and relatively in any direction to each other. The two eye-pieces of the instrument have at the planes where the images are formed each a small scratch on glass. When looking into the instrument these two scratches, as well as the photographs, combine stereoscopically, and there is seen a mark suspended in space on the landscape. By adjusting various screws, having scales or indices attached, this mark can be moved apparently over the landscape relief view in the three dimensions of space. Like a surveyor's rod, it can be moved about and placed at will wherever desired, the extent of its movements being accurately known by readings given on indicating scales. Hence it becomes possible to make from two carefully and properly taken photographs a complete survey of all the features of a landscape which are visible from two nearby points of view. By taking a number of sets of views from different standpoints the entire contour of the landscape can be surveyed. Methods are available for the conversion of focal coordinates, read off on the apparatus into co-ordinates of dimension. Thus drawings can be readily and exactly made at home on the plane table without any calculations whatever, use being made of the stereoscopic relief picture seen in the stereocomparator. The makers of this remarkable apparatus do not claim that the stereocomparator will replace the usual methods of surveying, but that both may be used to the greatest advantage side by side in mutual co-operation. Thus the special usefulness of the stereoscopic method in

surveying may be found for the production of most exact topographical plans, the construction of contours, profiles, and models, for the production of plans of inaccessible places, as chasms, mountain heights, and the like. The prospectus published in 1903 in English by Carl Zeiss summarizes the numerous applications of this instrument and methods to other purposes than surveying.

Thus, in stellar astronomy it may be used for the rapid detection and study of any small relative displacement of any of the celestial bodies. In observations on the sun the method is useful for studying the proper movements of sun spots as distinct from their common movement with the rotation of the sun. In observations on the moon the power of the stereocomparator is made marvelously manifest. Two photographs of the moon being taken at different intervals of time give the data for determining the height of the mountains on the moon and the diameter of the craters on its border by means of the traveling index.

The comparator finds also many uses in metronomy for the rapid comparison of scales, spectral lines, and the like. It is useful in meteorology, geology, and architecture.

It is regrettable that there is no adequate description in English of this latest and most interesting development of the Carl Zeiss works, but for those that can read German there will be found a most complete and satisfactory discussion of the stereocomparator, and the methods of using it, in a series of articles by Dr. C. Pulfrich in the "Instrumentenkunde" of 1902.

In conclusion, I wish to say that the applications here mentioned of our power of stereoscopic vision are only a few of those which are possible and useful, and I hope at some later date, after completing experiments on which I am at times engaged, to present other interesting and—it is to be hoped—useful facts regarding it.

DISCUSSION.

Walter Loring Webb.—Can the accuracy of the instrument in any way compare with the accuracy obtainable, for example, by stadia surveying, or could it ever replace stadia surveying?

Carl Hering.—Would it not give rise to considerable errors if the two photographs taken at the base-line were not exactly the same in focal distance? That is, suppose a man carried his camera from one end of the base-line to the other, and during that time the focal distance changed somewhat, would not that make a very great error in the measurements?

Dr. Northrup.—The accuracy of surveying by means of the comparator is remarkably high, but the people who manufacture it do not claim that it is anything more than an auxiliary to the other kind of surveying. It is especially adapted to giving topographic lines, or rather the heights and elevations and contour lines. The accuracy, however, compares very favorably with the other kinds of surveying up to a distance of two or three thousand meters where you have good vantage points, as in the Tyrolean Alps. They made a survey of the Tyrolean Alps with this instrument, taking their base-lines several meters apart, and obtained results that compared very favorably with the survey maps made in the usual manner. The telemeter, which depends upon the same principle, is claimed to measure up to 3000 meters within an accuracy of 4 per cent.

The methods described for taking the photographs I have not read carefully. I only read Dr. Pulfrich's conclusions in the matter, and he says that the photographs have to be taken with great precision. A large portion of his article is descriptive of methods and means of taking the photographs with extreme precision, so that the plates shall bear certain angular relations to the optical axis of the camera, and to the base-line, and other like matters. I have no quantitative results that I can quote. In fact, the instrument is so new that I do not know how thoroughly it has been tested in that regard, but I think it is very good, and I have seen the telemeter myself and it is astonishingly accurate up to small distances.

PAPER No. 1011.

THE BACTERIOLOGICAL TREATMENT OF SEWAGE.

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HISTORICAL REVIEW.

THE bacteriological era in the art of sewage purification dates from about 1882, when the agency of micro-organisms in reducing organic matter in soil to mineral compounds first began to be generally recognized.

The fact that sewage filtration was bacterial in character was not known when Dr. Edward Frankland undertook for the Rivers' Pollution Commission of England the first experiments of the kind to determine the effect of downward filtration of sewage through various soils.

These experiments extended over the years of 1868 and 1869. They showed that the action in the filter was twofold. First, mechanical; second, chemical.

Also that the first essential of filtration was aeration, to which end the operation must be intermittent to cause air to follow the sewage in the filter. It was concluded that by observing these requirements the sewage of 3000 people could be treated in one acre of porous well-underdrained soil.

This discovery, for such it should be called, marked the beginning of the decline of existing sewage disposal processes. It paved the way for the advent of the bacteriological era. For while it was shown that the new idea, called intermittent filtration, differed not from land treatment in these respects, that in both the suspended solids were first removed and the matter in solution was next purified by chemical action in the pores of the soil through absorption of atmospheric oxygen, yet intermittent filtration did more, it controlled, modified, and intensified the natural land operation, thereby permitting high rates and requiring less area.

The first practical demonstration of the new idea was made by Mr. Bailey Denton at Merthyr Tydvil in 1870–71.

It was vigorously combated by numerous stanch adherents of sewage irrigation. At that time the general supposition was that vegetation

aided the process of sewage purification on land to a considerable extent.

It had long been known that nitrates are continually being produced in soils. Also that it is due to a process of oxidation. Chemists had observed that when ammonia and nitrogen of organic bodies were oxidized in the soil, nitric acid was produced. In what manner this oxidation occurred, however, remained unknown, until early in 1877, when the French chemists, Schloesing and Muntz, published some experiments conducted at the Paris Sewage Farm proving that the nitrification in the soil is due to the action of a living ferment, existing in soils and impure waters.

Robert Warrington, an English chemist, pursued similar researches, and in 1882 published a paper on "Some practical aspects of recent investigations on nitrification," in which he pertinently stated: "If we wish to control the operations of nature, we must, in the first place, endeavor to understand them. Until we are acquainted with the mode in which any particular action takes place, and the influence exerted by varying external conditions, we are not in a position to govern the course of the action, or to employ it in our service."

Warrington declared that the purifying action of soil is due to three actions:

First, Simple separation of suspended matters.

Second, Retention by soil of ammonia and organic substances in solution.

Third, Oxidation of both by the agency of living organisms.

The first he showed to be a mechanical process, the second a chemical action, and the third, one depending on the first two and the biological conditions.

So from 1882 the term oxidation implied micro-organic activity. Some of the more important facts brought out by Warrington, concisely expressed, are as follows: A porous medium is not necessary, nitrification may occur in a bottle, but porosity is favorable to rapidity of the process. Aeration is an important function of speed. Sewage supplies the nourishment for the oxidizing medium. These organisms are present in surface soils in proportion to presence of organic matter. It is possible to construct artificial beds of greater oxidizing power than a soil. Porosity and underdrainage facilitate oxidation.

These facts shed a new and great light upon the whole sewage disposal problem.

During the previous quarter of a century the field of investigation

had been exhausted. Earth, air, fire, and water had all been resorted to, the resources of chemistry had been ransacked, and authorities, distrustful of processes in use, stood in the attitude of expectancy awaiting the advent of some miraculous invention or discovery to supplant prevailing practices.

One English writer, in summing up the situation just prior to Warrington's classic paper, said: "No chemical can efficiently deal single-handed with sewage, but must be assisted by subsequent natural filtration of the treated sewage, and, therefore, no chemical process *per se* should be adopted for the purification of town sewage.

"Where land can be reasonably acquired, irrigation is the best and most satisfactory known system for the disposal of sewage. No profit must be expected from the cultivation of crops by the sanitary authority and only a moderate one by the farmers. No definite standard can be laid down as to the proportion population should bear to acreage.

"Intermittent downward filtration may be practised, where irrigation cannot be reasonably adopted, but the term means no more than the production by deep drainage of a state of things frequently found in irrigation. Intermittent downward filtration, as expounded and explained by the Rivers' Pollution Commission, has never had and never can have any practical existence.

"Towns situated upon the seacoast, or within the tidal range of rivers, should avail themselves of the means of outfall thus presented, as affording the most economical and efficient means of dealing with their sewage, careful regard being always had to the position of the outfall."

In 1884 Mr. Warrington made public further important researches. He said: "It is difficult to conceive how the evidence for the ferment theory of nitrification could be further strengthened, for it is apparently complete in every part. Although, however, nearly the whole of this evidence has been before the scientific public for more than seven years, the ferment theory of nitrification can hardly be said to have obtained any general acceptance; it has not, indeed, been seriously controverted, but neither has it been embraced."

It was partly with the view of calling the attention of English and American chemists to the importance of the question that Mr. Warrington was induced to bring up the subject at that time.

Some of the points brought out in the paper are as follows:

Nitrification commences first in the weakest sewage, proceeds more rapidly in summer, is most rapid in darkness; strong light may cause

it to cease altogether, is quickest in a thin layer of sewage owing to greater supply of oxygen.

The nitrifying organisms are of slow growth. A solution *seeded* with a very small amount of them will long delay nitrification, but a solution receiving an abundant supply of the ferment will exhibit speedy nitrification. Strong solutions may by this means be successfully nitrified.

The speedy nitrification in soil is owing to the great mass of nitrifying organisms contained therein, also thinness of the liquid layer which covers the soil particles.

The hastening of sewage purification by bacterial inoculation suggested by Warrington was reiterated by Dr. Dupré in 1886. Speaking of the remarkable unanimity on the part of observers, that the dissolved organic matters, when the sewage was mixed with a certain quantity of water, would rapidly become oxidized, he said that he had "often thought that a very good thing would be to cultivate low organisms on a large scale, and to discharge them with the effluent into the river, as the power which these low organisms had was something remarkable."

The next public important discussion of the subject was in 1887, in connection with the disposal of the sewage of London. Mr. W. J. Dibdin, chemist to the Metropolitan Board of Works, was called upon in 1884 to devise some means of purifying the River Thames. The odors at that time from the sewage pollution of the river were most offensive, and public sentiment demanded their abatement.

Early in this experiment it was proved that a sterilizing agent such as chloride of lime produced an ultimate effect the opposite of that intended. The organisms of the sewage were destroyed and the offensive odor largely removed; but as soon as the dilute action of the river-water was sufficient to nullify the antiseptic action of the chloride of lime, the putrefactive organisms introduced from the river multiplied enormously, and the whole mass of sewage underwent putrescent fermentations, bringing about the original foul condition.

It was found, however, that when permanganate of soda was employed the oxidation of the sewage could be effected without putrefaction, because the permanganate prevented the increase of the putrefactive organisms while producing the condition necessary for the well-being of those through whose agency the organic matters were oxidized.

Thus sterilization of sewage was found to be a mistake and the prin-

ciple of Warrington further enunciated, that efforts should be made toward fostering the class of organisms by whose aid purification is finally accomplished.

In Mr. Dibdin's 1887 paper, he said: "The lesson to be learned from the numerous experiments published by various authorities, both in this country and on the continent, is that bacteria and other low forms of organic life are most potent in the destruction of all objectionable refuse. Modern experiments show that, when this subject is better understood and thoroughly worked out, in all probability the true way of purifying sewage, where suitable land is unavailable, will be first to separate the sludge, and then to turn into the neutral effluent a charge of the proper organisms, whatever that may be, specially cultivated for the purpose, retain it for a sufficient period, during which time it should be fully aerated, and finally discharge it into the stream in a really purified condition. This is, indeed, only what is aimed at and imperfectly accomplished on a sewage farm. It is true that knowledge on the subject is not yet sufficiently advanced to put such a system into practical operation, but sufficient is known to show that the antiseptic treatment of sewage is the very reverse of nature's method."

Mr. Dibdin, however, concluded that chemical precipitation was a process suitable for the purpose in view and would effect an enormous difference in the character of London sewage, that probably thirty years would elapse before any change would be required. Even then, should it happen that another chemical process far better in character should be discovered, not one farthing of the money spent for tanks and apparatus would be lost, for they would be equally available.

So it seems that in 1887 the oxidizing power of the Thames was purposely brought into play to complete the purification of a chemically clarified sewage.

Mr. Dibdin's views at that time with respect to filtration were pronounced. He said: "The alternation, so often proposed, to the precipitation process for the collection of the sludge is filtration. This system has been advocated in so many different ways, and every conceivable material proposed for it, that it would be a useless task to enumerate them. Fortunately the outcome of them all is the same —rapid choking of the filters; frequent cleansing; heavy manual labor; unmanageable quantity; sludge mixed with filtering material, etc. As regards the question of sludge, it is generally admitted by practical sanitarians that filtration is out of the question. As effecting

the further purification of a clarified sewage, filtration is without doubt a rational process in all respects save one, and that is, expense. If further purification is desirable, and suitable land can be obtained, filtration is the form of effluent farming to be commended beyond all other proposals. But land must be suitable, and not over-dosed with the liquid to be purified, otherwise ultimate failure is a foregone conclusion."

The adoption of the chemical precipitation process by the English metropolis, in the face of repeated failures of the method throughout the kingdom, coupled with Mr. Dibdin's adverse position toward filtration, put a quietus, for the time being, on progress in sewage filtration in England.

So the time was ripe for the now world-renowned classic researches of the Massachusetts State Board of Health.

These experiments were begun the latter part of 1887, and have been continued to date. The first report was made in 1890. The object sought was, to find out the way in which the organic matter in sewage can be completely oxidized. Previous to these investigations, little was definitely known of the conditions most favorable for the purification of sewage, by any given material. The Lawrence experiments were undertaken to learn what could be particularly accomplished by filters composed of various Massachusetts soils.

As nitrification takes the leading place in the process of purification of sewage, the conditions most favorable to the action of the nitrifying organisms were regarded as essential, namely, the presence of oxygen, of organic matter, of moisture, and of some alkali, and a favorable temperature.

As would be expected, the old fact was demonstrated again that flowing sewage over porous sand strains out large quantities of the suspended matters and finally clogs the strainer, and the effluent will be as impure as the applied sewage; but it was further found that if only so much sewage be applied as will pass through the sand and allow the screened matter to dry up or become oxidized, the operation may be carried on indefinitely.

A filter 5 feet deep of washed gravel stones, dosed nine times a day with crude sewage at the rate of 126,000 gallons per acre daily, removed 98 per cent. of the ammonias and destroyed 99 per cent. of the bacteria.

These results conclusively showed the essential character of intermittent filtration (so called) to be bacterial. It was not a straining process. Small quantities of sewage hourly applied over the whole

filter surface covered each stone with thin films of liquid, exposed it to contact with air held in the spaces between the stones within the filter, and within twenty-four hours—the time required for the liquid to reach the bottom from the top—the organic matter was oxidized. The stones were as clear after a year's use as in the beginning. The action was not mechanical, but chemical and bacterial, by which the organic substances were reduced to mineral products, the effluent in every respect comparing with water in wells and for drinking purposes.

With coarse sand filters it was shown that 60,000 gallons of crude sewage may be filtered daily on an acre removing 97 per cent. of the organic matter, about all the bacteria, and giving an effluent colorless and clear.

With fine sand it was shown that 25,000 gallons of crude sewage per acre daily may be filtered indefinitely. Many people drank of this effluent without unpleasant effects.

An intermittent sand filter which removed 99 per cent. of the applied organic matter was later operated continuously like a sand-water filter. The surface was covered with sewage, excluding air and filling the spaces with liquid. When so operated, purification ceased. The essential difference between the intermittent and the continuous filter was exclusion of air in the latter.

Instead of Dr. Dupre's and Mr. Dibdin's forecast that the time would come when it would be found practical to cultivate a special organism and introduce it into the sewage coming true, the Massachusetts experiments proved Warrington's position, that the bacteria effective for the purpose are found to be freely present in the sewage and merely require the necessary conditions to enable them to accomplish their work.

The publication of the Massachusetts experiments was at once followed by efforts of the London County Council along similar lines to obtain reliable working data on filtration, based upon something more than mere laboratory trials.

Mr. Dibdin was directed in March, 1891, to conduct a series of experiments as to the best methods of filtering the sewage effluent of the northern outfall precipitation works at Barking.

Preliminary tests during 1892 proved coke-breeze to be the most suitable material for trial on a large scale. This next experiment was with a one-acre filter. It began in 1893 and was continued to the autumn of 1895, when Mr. Dibdin made his report.

Toward the end of 1894 the chemically clarified sewage was passed

on to the acre filter at the rate of 1,000,000 gallons daily. The method of operation was novel. The liquid was allowed to fill the filter as quickly as possible to just level with the surface, then allowed to remain standing in the filter for one hour, when it was drawn off with the least possible delay. The filter so worked was given a period of one day's rest each week.

The conclusions were that clarified sewage may be purified to any degree, the actual amount of purification depending upon, first, the length of time sewage is held in contact in the filter; and, second, the length of time allowed for aeration.

In no way did these principles differ from those enunciated in the Massachusetts reports, but his method of obtaining contact—by means of gates instead of frictional resistance of the filter material—was new, and later gave to the structure the term "contact beds," although Mr. Dibdin designated them "bacterial filters."

From the experiments with clarified sewage Mr. Dibdin reasoned that if the organisms had been able to accomplish so great a destruction of the fine suspended matters in the sewage, why should they not be equally potent for the destruction of the larger particles in crude sewage, which in the aggregate form what is known as "sludge." It was evident that if these coarse matters were placed on the fine bed they would speedily accumulate on the surface and form a deposit of putrefying matter. By making the bed of coarse material the sludge would be able to penetrate into the filtering mass, settle on or be attached thereto, and there be subjected to aerobic bacterial action. These considerations led to the construction of the first coarse sludge bacterial filter of the Dibdin type. It was brought into use November 20, 1896, at Sutton, England. The effluent therefrom was treated in a secondary bed of fine material.

When Mr. Dibdin made this too hasty venture in sludge treatment, the whole trend of thought generally was toward the acceleration of bacterial processes.

It was generally known in respect to slow filtration, by those practising the art or following the Massachusetts reports, that fresh sewage contained suspended organic matter of coarse character, that they were readily strained out, remained on the surface, clogged the filter, retarded the flow of sewage into the filter, prevented proper aeration, and interfered with purification; while in stale sewage the suspended organic matters were finely divided—mechanically, chemically, and bacterially—so that less surface clogging would occur, the larger per-

centage of the solids passing into the filter, where they were changed into inorganic form and passed away in the effluent or into the air as nitrogen or carbonic gas. Further, that clogging was always in proportion to the sludge; that the amount of sludge in sewage varies; that any sewage will in time clog a filter unless great care is used; that a greater percentage of sludge is stored at a high rate than a low rate; that the same quantity stored causes more trouble at a high rate; that a clogged sand filter will slowly oxidize when rested, and that permanency is independent of size and material, but depends on the treatment.

It was generally known, in respect to rapid filtration by sand of sewage from which the sludge had been removed, that a rate of from 160,000 to 240,000 gallons per acre daily of settled sewage, from 200,000 to 360,000 gallons per acre daily of chemically subsided sewage, that 300,000 gallons per acre daily of coke-strained sewage, and that 650,000 gallons per acre daily through sand and 700,000 gallons per acre daily through coke—of sewage first treated by rapid filtration through coarse gravel aided by a current of air drawn downward—could be indefinitely maintained.

It will be noticed that the indispensable element of all these accelerated processes was the preliminary removal of the sludge.

Mr. Dibdin's departure from this principle was radical. It caused a commotion.

Even in the Massachusetts rapid and forced aeration filters not all the organic matter was destroyed. Some remained in the filters and some came off in the effluent and went onto the surface of the fine or secondary bed, limiting it to an extent.

While the Sutton aerobic bacterial sludge bed overshot the mark, accumulated organic matter, and had to be subsequently overhauled, it did extend the bacterial disposal of sludge in a filter far beyond what had hitherto been suspected possible.

It is to Mr. Dibdin's everlasting honor that he did not aspire to the position of a proprietary owner, but gave to the world at large the results of his researches and inventions.

That the names of Frankland, Warrington, and Dibdin will always be associated in history with the progressive steps in the bacterial purification of sewage is an assured fact.

We now come to a consideration of that period which is most interesting of all—the present; the one in which the aerobic and nitrifying organisms do not command all the attention. Previous to this

time anaerobic bacteria had been intentionally and successfully utilized in the disposal of sewage sludge on a practical scale in several countries. English authorities, however, had not taken up with the method, presumably because they were wedded to the deodorizing and oxidizing processes, requiring the sewage to be in as fresh a condition as possible.

In 1869 Dr. Alexander Müller of Berlin made some experiments on "the self-purification of sewage," which were published in 1873 in "Landwirthschaftliche Versuchstationer," volume XVI, and on page 263 of this publication Müller remarked as follows:

"The contents of sewage are chiefly of organic origin, and in consequence of this an active process of decomposition takes place through which the organic matters are gradually dissolved to mineral matters. To the superficial observer this process appears to be a chemical self-reduction; in reality, however, it is chiefly a process of digestion, in which the various animal and vegetable organisms utilize the organically fixed power for their life purposes."

In 1878 he took out a German patent for a process of "disinfection, purification, and utilization of liquid sewage by the rational cultivation of fermenting organisms."

Mentioning the difficulties of sewage treatment, the specification goes on to state: "The attempt at removing the nuisance by dilution on a large scale, or obviating putrefaction by means of antiseptics, or, again, precipitating the noxious substances by means of chemicals, or absorbing them by both filtration or oxidizing them direct, by atmospheric oxygen over a large contact area, have proved futile.

"Observations and investigations continued for many years have led inquirers to the conclusion that on purely mechanical or chemical lines the object aimed at was not attainable." "Now whereas the former disinfecting methods had for their essential object to obviate as far as practicable any phenomena of putrefaction, the process herein described, on the contrary, aims at the methodical cultivation of those small 'level-like' organisms to the viability of which modern science has traced the so-called 'self-unmixing' processes, namely, acidification, fermentation, putrefaction, decay or the like, with a view to bringing them into requisition in the task of precipitating out the liquid waste-substances or bringing about their complete mineralization.

M. Louis Mouras's "automatic scavenger" was patented in France in 1882. It was fully described in publications of the times. It had

for its object the solution of the cesspool problem of Paris. Up to that time all public measures had failed. His invention had been used in his own house for twenty years with success. It comprised a tank hermetically sealed, with submerged inflow and outflow pipes, working on the continuous principle, receiving house sewage and accomplishing the liquefaction of the solids through putrid fermentation. It was thought possible that the unseen agents might be those vibrions or anaerobies which, according to Pasteur, are destroyed by oxygen and only manifest their activity in vessels from which the air is excluded. Daily observations conducted with a glass showed that fecal matters introduced on the tenth of August were entirely dissolved on the sixteenth of September. Even kitchen refuse, onion peelings, etc., which at first floated on the surface, descended after a time to the bottom of the vessel to await decomposition. Everything capable of being dissolved acted in a similar way, and even paper wholly disappeared. Subsequently the process was applied on a practical scale in France and Italy.

Mr. W. D. Scott-Moncreiff, C. E., of Ashtead, Surrey, England, apparently stumbled upon the liquefaction process in 1891. He installed a simple upward filter plant at his country home.

He did not anticipate the results which followed. Instead of a mechanical action, he discovered that the apparatus provided a favorable condition for the development of organisms which changed the organic matter into a clear, inoffensive effluent. Straightway he improved the apparatus, termed it a "cultivating filter," and exploited the discovery of continuous purification of sewage by bacteriological action through aerobic liquefaction.

In the autumn of 1892, through the assistance of Dr. Sims Woodhead, he secured the services of Dr. Houston, and together they set to work to find out what was going on. A laboratory was established at Ashtead and the various bacteria were identified. In 1894 Mr. Scott-Moncreiff was enabled to positively name certain liquefying organisms, whose cultivation it is the object of his invention to accomplish. At that time the system was at work at various country houses in England.

The absolute destruction of all organic sludge was claimed for the process.

Next upon the scene appeared the "Exeter septic tank." Mr. Donald Cameron's pretensions to proprietorship in the anaerobic liquefying process is a most conspicuous illustration of the proneness of

humanity to appropriate a desirable thing found lying around loose.

The pat application of the term "septic" to a very old principle, in contradistinction to the term "antiseptic" applied to many prevailing English processes, publicly paraded as an absolute solution of the sludge problem just at the time when an open door to perfect bacterial purification was earnestly anticipated, vouchsafed a welcome to Cameron's tank at first limited only by the bounds of human credulity.

An experiment was begun on a small scale at Exeter, England, on April 5, 1895. On November 8th he applied for protection for his invention, whose object was stated to be "to deal with crude sewage bacteriologically and bring it into such a condition of solution and liquefaction that it can be treated by filtration." It was claimed by the inventor that the solid portions of crude sewage were entirely thrown into solution.

The first tank was small, 12 by 15 feet by 2½ feet deep, dealing with the sewage of about thirty houses. No filters were attached to it. Little sediment occurred on the bottom, but thick scum formed on the surface of the water.

The next tank was about double the capacity of the first one. It was started in January, 1896, to show the Corporation what could be done by this system of disposal. Two coke-breeze filters were attached and operated at a rate of about 1,000,000 gallons per acre daily. As the result of the working of this installation, the Council decided to construct larger works to show to the Local Government Board the system on a practical scale. These were brought into use July 21, 1896. Dibdin contact beds were attached and operated by automatic apparatus invented by Mr. Cameron.

A second British patent for the perfected system and apparatus was applied for in October, 1896.

The earlier Massachusetts experiments were not directed toward putrefaction processes, but toward nitrifying ones. It was sufficient at first to conclusively prove that oxidizing or aerobic agencies were ample to completely break up and mineralize organic matter, sludge and all. In the 1893 report the first distinction between fresh and other sewage was made by calling attention to the presence of dissolved oxygen in the former and its absence in the latter. It was also observed that fresh sewage was harder to purify, because it contained a larger proportion of organic matter in suspension. The bacterial process following this initial step in sewage purification was shown

to be evidenced in the arrangement of the free ammonia, organic nitrogen, and by the loss of carbonaceous matter. In other words, in stale sewage—one containing no free oxygen and in which the facultative anaerobes do the work generally called putrefaction—there is a loss of crude organic matter by the reduction of carbonaceous bodies and the changing of organic ammonia to free ammonia.

The fact that the percentage of suspended organic matter present in sewage decreases with the increase of age of the sewage, and that stale sewage is more easily disposed of upon sand filters than fresh sewage, was repeatedly stated in the four annual reports of the Board prior to its first use in 1898 of the term, "septic."

In relation to the putrefactive principle, the adoption of the term "septic" became necessary owing to the general use of it since the publication of the Exeter experiments.

In so far as Cameron's apparatus is novel, he is entitled to the benefits of the invention, but that he rightfully owns the exclusive use of the liquefying process, anticipated as it was both in recent and former years, is most earnestly disputed.

At any rate the year 1898 was characterized by great advancement in the knowledge of the particular part aerobic and anaerobic agencies independently play in the work of purification. All eyes turned to England and the Massachusetts work was temporarily forgotten.

Both Scott-Moncrieff and Cameron had differentiated between the preliminary or hydrolytic change and the final one of oxidation or nitrification.

Bacteriologists at once set to work to supply the deficiency in the knowledge of the bacterial chemistry of these processes. To comprehend the subject, as it stands today, one must know about the position taken by different authorities at that time.

It became evident that the septic tank, by means of its bacterial enzymes or spontaneous chemical decomposition, materially altered the composition of the raw sewage. The increase of the total solids pointed to a solvent action of the water on the matter in suspension, due to a digestive or purely physical process; but the marked disappearance of organic matter and transference of organic nitrogen to free ammonia was due to bacterial influences.

Dr. Rideal concluded that the bacterial transformation of sewage occurs in more or less distinct stages, which he enumerated as the "initial stage," or the transient aerobic one, the "second stage," or semi-anaerobic breaking-down of the intermediate dissolved bodies, and the "third stage," or complete aeration and nitrification.

In advocating anaerobic treatment as a final process he was not prepared to call the destruction or dissolving of organic matter in Dibdin's coarse bacterial filter aerobic. The action must be anaerobic under aerobic conditions, since it is hydrolytic. In the contact filter there are the opposing aerobic and anaerobic actions. The "resting full" period diminished the aerobes and the "resting empty" period diminished the anaerobes. This oscillation, in his opinion, tended toward defeating the very object of the filter. A preferable system is one in which anaerobic work is done separately, under uniform conditions, and the same respecting the aerobes.

Therefore, in constructing sewage disposal apparatus according to his views, it should consist of two parts, one for the preliminary anaerobic action and the other for the subsequent aerobic action.

Doctor Adeney, however, took the position that the supporters of anaerobic fermentation were working under pure hypothesis and that results could be explained in another way. Organic matter underwent two successive organic and distinctly different stages of chemical change, a fact of practical value, because the second stage of fermentation presented little danger to river-water, while the first stage in the absence of sufficient oxygen invariably sets up putrefaction. He found that aerobic fermentation will take place in sewage to the exclusion of anaerobic, so long as the supply of oxygen is present, and, further, that the condition under which bacteria effect chemical changes most rapidly is that in which oxygen is supplied to them in the atmospheric form, in which form the fermentations are unobjectionable to the senses.

Professor Ward profoundly summed it all up as a process of change brought about only by a living fermentation. If, however, at the same time there are produced evil-smelling gases, then fermentation is often called putrefaction. But attempts to separate, artificially, putrefaction from fermentation and restrict the former to the breaking-down of matter, and to distinguish between putrefaction which gives off no evil odors and putrefaction which does give off evil odors, is fallacious.

No such lines can be drawn. Putrefaction is merely a particular case of fermentation, and the most comprehensive definition of fermentation is "change produced in various bodies by the action of living organisms."

Many bacteria are aerobic and many others are anaerobic, and there is a point somewhere between these extremes, which is now gen-

erally called the optimum, where the actions are going on at their best, and, of course, the thing to do is to find out their optimum conditions. In addition to these are the extraordinary physiological class of bacteria called facultative anaerobes, which can be either anaerobic or aerobic, according to circumstances. It is possible for anaerobic fermentation to go on near the oxygen-supply, as at the surface of liquid, provided some other organism protects the anaerobe from the oxygen. That is to say, the physiological action is going on in a different direction from the direction in which either of these alone would carry it. So that symbiosis, as it is called, comes to mean the action together of two living organisms, where the action of each does not hinder, and in most cases helps, the other. This explains the disappearance of so much crude sludge in Dibdin's coarse contact filter acting under aerobic conditions.

Considering the complex fermentations existing in a mixture like sewage, symbiosis must be going on at various points, according to whether the sewage is in motion or quiet, or deep or shallow, and so forth. So the attempt to uphold putrefaction as a particular process, in which evil-smelling gases come off, brought about by anaerobic organisms, must fail. Either kind of fermentation may produce putrefactive gases.

Professor Ward concluded that it was not necessary to provide for the destruction of sewage in special anaerobic compartments. The anaerobic process is not the normal one in the events of nature. The nitrate is the desired goal of the change, and the antecedent phase to the nitrate is always an ammonia phase. The reduction to ammonia is accomplished by a large variety of organisms, some working in an aerobic and others in an anaerobic way. It is not necessary, therefore, that the process should be one of exclusive anaerobic condition. The aerobic organisms will bring all but the cellulose bodies to the ammonia condition most rapidly.

The next important device to be exploited was the Whittaker type of continuous sprinkling filter. In striving to obtain uniform distribution of sewage Mr. Whittaker adopted parallel troughs, but they did not work well, so he substituted the sprinkling arrangement, and the results were at once satisfactory.

A summary of what is now known about bacterial treatment of sewage by the processes hereinbefore mentioned may be briefly stated as follows:

First, A limited period of anaerobic action is advantageous.

It may occur in the filter or in a septic tank.
It prepares organic matter for the oxidizing bacteria.
Causes the large particles of suspended matter to break up.
Dissolves a part of them or liberates in gaseous forms.
Remainder finely divided.
Can be purified at higher rates than fresh sewage.

Second, Too advanced stage of anaerobic action a disadvantage.
Such effluent absorbs oxygen before nitrification can take place.
Toxic bodies therein kill nitrifying organisms.

Third, Septic tank accumulates sludge.
Requires to be emptied.

Fourth, Anaerobic filters are successful.
Give better results than septic tanks.
Furnish greater surface for bacterial growth.
More difficult to keep in working order.

Fifth, Continuous filters can be operated at highest rates.
Require preliminary treatment of sewage.
Air and sewage in continuous contact throughout entire depth.
Free oxygen present in open space all the time.
No accumulation of carbonic acid or marsh-gas in filter.
Gives best rapid filtration results.

Sixth, Contact filtration supports both anaerobic and aerobic fermentation.
This cycle is advantageous.
It lessens clogging and promotes more rapid purification.
When drained, oxidation of intercepted matter proceeds until oxygen is all used up.
The resulting products—carbonic acid, marsh and nitrogen gas—fill the open spaces.
Marked anaerobic action begins at this point and continues until bed is filled and drained again.
The filter material must be coarse enough to pass suspended matter or it will accumulate and require physical removal.
Clogging should be minimized by preliminary sludge removal.
The methods, in order of preference, are septic, settling, and straining tanks.
Mineral matter must pass away in effluent to insure filter permanency.
The filter should be filled with sewage once daily only.
Successive applications, instead of steady flow, best way of filling.

This allows greater degree of aeration.

In double contact the fine filter may be of lesser area.

It is aerobic and should be drained before oxygen is exhausted.

Time limit should be not over two hours from complete flooding.

Seventh, Slow sand filtration gives most perfect degree of purification.

The rate may be increased by first removing the sludge from the sewage.

The methods in order of efficiency from least to greatest are:

Sedimentation,
Chemical precipitation,
Septic tank,
Coke straining,
Straining and forced aeration.

Aeration before application of effluent to filter, advantageous.

Eighth, Effluents of rapid aerobic filtration process are of stable character.

Considerable suspended matter found therein.

When dry is granular, loam-like, and inoffensive.

Resists bacterial action and secondary decomposition.

This is of practical value where a stream is handy into which a partially purified effluent may be safely discharged. As in Dibdin's early Thames problem, the diluting and oxidizing capacity of a convenient river or body of water may be a factor in the solution of a disposal problem.

The following table gives the rates in gallons per acre daily which may be maintained by the several processes:

Kind of Sewage.	Method of Preliminary Treatment of Suspended Solids.	Type of Bacterial Filter.	Rate of Operation, Gallons per Acre Daily.
Fresh	No treatment.	Slow sand.	100,000
Stale	Plain subsidence.	Sand.	150,000
"	Chemical subsidence.	"	200,000 to 360,000
"	Coke straining.	"	320,000
"	Gravel filtration aided by current of air.	"	660,000
"	No treatment.	Spraying coke.	600,000
"	" "	Double coke.	600,000
"	Plain subsidence.	Continuous aerobic, broken stone.	1,400,000
Septic	In septic tank.	Sand.	40,000 to 150,000
"	" " "	Spraying, sand.	300,000
"	" " "	Contact.	660,000 to 800,000
"	" " "	Continuous sprinkling.	1,400,000

Plain Subsidence and Sand Filtration at Brockton, Massachusetts.

The early experiments of the Massachusetts State Board of Health are well illustrated on a practical scale at the Brockton Disposal Works. This plant was designed in 1891–92 and put in commission in 1894. The sewage is settled by plain subsidence and filtered through sand. The population of Brockton is about 45,000. The per capita consumption of water varies, but averages about thirty gallons. The sewage, therefore, is concentrated. In fact, it is the strongest in the State.

A covered reservoir of 500,000 gallons capacity stores the sewage of the latter part of each day and the entire night-flow. Every morning the content is pumped three miles to the disposal area.

An agitator rests on the bottom of the reservoir, by means of which the solid matters collected on the bottom may be stirred up. The agitator is put in operation just before the reservoir is emptied, and the entire body of the sludge is then mixed with this small amount of sewage. After the reservoir is emptied the pumps are stopped, and this doubly concentrated sewage remains in the lower end of the force main until pumping is resumed the next morning. It is then discharged at the filter beds. Special filters are allotted for the sludge.

The reservoir sewage and that stored in the force main are considerably decomposed.

After the heavy sewage is filtered there remains upon the surface of the beds a thin layer of solid matter, which readily dries out and is raked up and removed for burning or other disposal.

The filters are an acre in area each and there are twenty-two of them. They are underdrained, provided with surface sluice distributors of novel design, and are dosed daily at the rate of 80,000 gallons applied in about twenty minutes. The gates controlling the operation of each bed have to be manipulated by hand.

Crops are raised on some of the beds. This was tried for experimental purposes. It has now been abandoned.

"The beds are prepared for winter use by plowing, the surface being ridged and furrowed. Those receiving the supernatant liquid require very little attention. They are raked once each year only. Sludge beds are raked about once every month and the sludge is removed three times yearly. The cost of doing this for 1904 was thirty cents per ton of dry sludge handled, the total for the year 1904 being $914.05.

A chemist is in charge of the laboratory at the beds, and a very complete record of the work done there is kept.

For 1904 the cost of pumping the sewage was $3812. The cost of labor at the beds was $4412.71 and the part of the City Chemist's salary chargeable to the Disposal Works was $840. The total cost of operation on this basis per capita, per annum, is twenty-one cents. The total first cost of the works—*i. e.*, the reservoir, pumping station, force main, and disposal area, including engineering and inspection—was $209,771, or about $4.66 per capita.

The purification of the sewage is very complete and the system is accomplishing all that was anticipated for it.

Septic Subsidence and Automatic Regulated Sand Filtration at Saratoga Springs, New York.

The largest American installation of sand filters receiving septic tank effluent, automatically distributed, is at Saratoga Springs, N. Y. This plant was an outgrowth of the Brockton system. Its study was begun in 1899 and its practical consummation was a pronounced advancement in the art.

The sewage is raised continuously by automatically regulated centrifugal pumps, three in number, each driven by a directly connected, vertical, six-pole, twenty H. P. induction motor, using a three-phase current of fifty cycles frequency. Since the power is obtained from the Hudson River Power Company, and the automatic starting and stopping apparatus is entirely satisfactory in its operation, no constant attention is required at the station.

The septic tanks effectively dissolve the suspended solids, thereby serving, as designed, to keep the beds clean and to keep the cost of their maintenance down to the minimum.

The automatic dosing tank and apparatus is of novel design. It is simple and positive in its operation and makes possible the application of the sewage regularly during the day and night in doses of the desired amount with no attendance other than occasional oiling.

The works have been in operation since July, 1903. The summer population of the resort is 50,000. The volume of sewage treated varies from 1,250,000 gallons in winter to 2,500,000 gallons daily during the height of the season.

The pumping station is on the outskirts of the village. The septic tanks, four in number, each 51 by 91 by 8 feet, covered and having a total capacity of 1,000,000 gallons, are located at the disposal area 8835 feet distant from the station.

The filter beds are twenty in number, eighteen of which are each one acre in area. Suitable sand was found in natural position. The filters are similarly arranged, with respect to surface distribution, winter furrowing, and underdrainage, to the Brockton filters. They have purified effluent sewage at the rate of 150,000 gallons per acre daily.

The septic tanks have required no attention; they have not been emptied.

The accumulations therein are no more now than a few weeks after starting. They occupy about 25 per cent. of the tank capacity. About 65 per cent. of the suspended solids have been removed by the process, and the remainder passing out of the tank is so finely comminuted and decomposed as to nullify its capacity for forming deposits on the filters.

No surface raking of the filter surface is necessary. The cost of surface management, including preparation for summer and winter work, is $560 per annum; the weeding and trimming of embankments, etc., $1120; the purchase of power for pumping, $720; attendant and removal of screenings at station, $600. For 1904 the cost of pumping the sewage was $1320, the cost of maintaining the disposal area was $1680. The cost of operating the whole plant for one year, on the basis of 40,000 people, was, therefore, seven and one-half cents per capita. The first cost of the works was $100,000, or $2.50 per capita.

Automatic Septic Tank and Contact Filtration at Mansfield, Ohio.

The next American plant of a distinct type and embodying novel arrangements was built at Mansfield, Ohio. It was designed in 1899, being an adaptation of the essential elements of the Saratoga design to the Mansfield requirements.

Natural sand deposits were not available, chemical precipitation was prohibitive in cost, so contact filtration was adopted. Preliminary treatment of the sewage in a closed septic tank was thought necessary.

The city has upward of 20,000 population, 12,000 of which contribute to the sewers. The system takes storm-water, but the dry weather flow in the sewers is about 1,000,000 gallons daily. This much sewage is always passed through an intercepting chamber which diverts surplus storm-water to the river. The dry weather sewage

is conducted by gravity to the septic tanks and part of it is pumped. The novel feature of the design of the septic tank is that the discharge therefrom is controlled by an automatic device, operated by floats which keep the said discharge constant, although the flow into the tanks varies from hour to hour. This necessitates a daily variation in the elevation of the surface of the sewage in the tank, but it had been previously ascertained at Brockton that this did not prevent the formation of surface scum or interfere with septic action.

It is obvious that regularity in food- and air-supply to a bacterial filter should be conducive to greatest bacterial activity. Dependence on manual manipulation of appliances to accomplish this regularity has its serious objections. In resorting to apparatus to accomplish the same thing automatically, one great difficulty is that the apparatus cannot depend for its regularity of action upon the rate of flow of sewage, because this flow fluctuates. Hence, some storage and equalizing are necessary.

The other difficulty with automatic gear, depending on sewage flow, is that the cycle of one bed is dependent on the conditions as to capacity, character of surface, etc., of another bed, which will vary according to circumstances. But this difficulty is not so important, because the said conditions are inherent in the filter and common to any kind of system of distribution of sewage and collection of effluent.

The contact filters are five in number, each of which has an area of one-fourth acre and contains about five feet of cinders—one-eighth to one-half inch average diameter—prepared by specially designed crushers and screens, which removed all worthless and crumbly material and all particles of less size than one-eighth inch. The total filtering area is laid out in the form of a circle, of one and one-fourth acres, so that each bed forms a sector of this circle. In the center of the circle is a small brick building containing the actuating mechanism which controls the flow to and from the beds, and does it not only at no cost, but with a regularity impossible of attainment by manual labor.

The sewage in leaving the septic tank is discharged over a weir into the outlet chamber in such a way as to thoroughly spray and free the liquid of the gases resulting from the anaerobic treatment. Connected with this outlet chamber, and immediately opposite the point of discharge of the weir, are ventilating pipes leading to the chimney of the garbage crematory. In this way all odors are rapidly carried off. The sewage is then conducted to an aerating chamber, where it falls

over a series of steps and is thoroughly exposed to the atmosphere. In this way the dissolved oxygen is effectually increased and the effluent thoroughly prepared for the final aerobic action upon which its purification in bacteria beds depends.

Thus it is seen that the separation of the aerobic from the wholly anaerobic treatment was deemed essential and amply provided for in this design.

In operation, four of the beds are in action at one time, the fifth being thrown out by the apparatus itself, for a period of rest of one week. Of the four in use, one is being filled, one is standing still, one is emptying, and one is resting. The cycle is completed in from fifteen to eighteen hours, and the period of contact averages four and one-half hours.

The works have given entire satisfaction. They have successfully accomplished the object for which they were built, viz., to obviate the pollution of the Rocky Fork River and to treat the sewage of the entire city.

The total cost of the works, including land, engineering, a garbage crematory, and one mile of outfall sewer, was $87,093. This is a per capita cost of $4.35. The cost of operation for 1904 was $3123.47, of which $2282 was for salaries of engineer and fireman at the pumping station. The total also includes the cost of cremating the garbage of the city. Outside of the pumping station and the garbage plant, practically no money has been required for operation. The tank and filters cost but a few dollars per year to operate. The per capita cost on the basis of this whole expenditure for operation was 15.6 cents for the year.

Crude Sewage Disposal by Dilution at Atlantic City, N. J.

The very best method of sewage disposal is into a body of water where favorable conditions prevail. Here it is treated by bacterial agencies unaided by man.

Some most interesting facts have been brought out in connection with tide-water disposal of crude sewage at Atlantic City. The present point of discharge is into the back waters of Beach Thoroughfare, remote from habitations and about two miles distant from the pumping station. The ocean beach has always been kept religiously free from even the suggestion of pollution of any kind, the active efforts of the City Board of Health in this respect vouchsafing to the public the maintenance of the highest sanitary standards.

The rapid increase of late years in the volume of sewage brought up the question of the advisability of treating it artificially. Investigations proved that to purify the sewage by sand filtration would cost over half a million dollars.

Street drainage is discharged into the back thoroughfare waters. The unpreventable pollution from this source is considerable, but the waters are amply able to oxidize these impurities. It therefore clearly appeared that circumstances did not require an extremely high degree of sewage purification.

Then it logically followed that, if only a partial purification were to be sought, an expenditure of $375,000—the estimated cost of contact filtration—would be out of all proportion to the benefits derived by the process, because it was found that the impurities which would be intentionally passed through the filters into the Thoroughfare for further oxidation would not tax the oxidizing capacity thereof. So if this much impurity were to be put into the stream, there was no reason why more should not be turned in also.

By this method of elimination it was finally concluded that the inland waters were amply able to successfully dilute and destroy all the crude sewage of the city.

The present force main now discharges at a point two and one-half miles distant from the ocean. The sewage itself contains no free oxygen. The water directly over the sewer outlet at high tide contains 16.5 per cent. Twenty-five feet away it contains 78 per cent., and in the center of the channel, three hundred feet away, 87.8 per cent.

This shows how great and rapid is the dispersion of the sewage at this point at high tide, and at low tide the dilution is nearly as great.

For tracing sewage in a stream bacteriological tests are more delicate and they show more readily what becomes of the sewage. At high tide at the sewer over 1,000,000 blood temperature organisms were found in a cubic centimeter of water, but in the center of the channel opposite only 250 were found. Between the sewer and the ocean at low tide, when the greatest pollution would occur, there were 960 blood temperature organisms in a cubic centimeter of water taken 1000 feet distant from the sewer; 2000 feet distant there were 875; 4000 feet distant there were 550; one mile distant there were 175, two miles distant 125, and near Absecon Inlet only 7.

The wonderful bacterial dispersion and destruction in these waters more fully appears when the bacterial content is compared with that of various streams used for public water-supplies. The average at

the following cities, Lawrence, Youngstown, Pittsburg, Louisville, London, Berlin, is 4100. At Atlantic City for all stages of the tide the average is 301.

The dissolved oxygen tests showed that from four to nine times the estimated volume of crude sewage in 1920 can be disposed of in the Thoroughfare at the sewer outlet without producing a nuisance. The chemical tests showed these factors to be from four to seven. The bacteriological examinations demonstrated the waters to be superior to many streams serving as sources of filtered public water-supplies or used for aquatic pastimes.

The purification cannot be accounted for by sedimentation.

A profile of the bottom of the channel at the sewer outlet, taken in the summer of 1903, compared with one taken at the same place a year later, showed a very considerable scouring of the sand to have occurred. An extended current meter measurement of the tidal velocities at all stages and depths showed the bottom velocities to be considerably in excess of those required to move sewage deposits. Therefore favorable conditions for sedimentation do not exist there.

Confirmatory evidence of the scouring force of the current was found in the chemical analyses of the waters, which showed large amounts of suspended solids, mostly of a mineral character. The preponderance of the scouring over the subsiding forces was also proved by comparing relative amounts of total nitrogen in mud taken from different parts in the thoroughfare with a sample of mud non-polluted by sewage.

The conditions at Atlantic City are favorable for the bacterial treatment of sewage in water. Before this conclusion was reached the local clam and oyster industry was most carefully studied with special reference to sewage contamination. This study materially influenced the final design, which provides storage reservoirs planned to discharge only on the first four hours of the ebb tide.

In its primitive condition the Thoroughfare was free from artificial pollution, and now, in consequence of a large city being located on its banks, some pollution is inevitable, and this unpreventable pollution renders storage of clams and oysters in these waters undesirable. The vigilance of the Board of Health has entirely prevented this practice.

The fact that the mere existence of a thickly populated community on a tidal body of water establishes a zone of suspicion with respect to the shell-fish industry therein suggests the necessity for adequate legislation to regulate the traffic in this zone.

Proprietary Claims.

In concluding the foregoing brief description of four American disposal works, each being a distinct type of bacterial treatment, the writer feels called upon to refer again to patents. Proprietary bacterial methods have not up to this time gained a strong hold in America nor in England. Public moneys have defrayed the expense of experiments, the results have been freely published, and attempts to patent borrowed ideas, or to get a legal monopoly of this kind of a public necessity, are frowned upon.

This refers to the processes themselves and not to appliances.

In the writer's opinion none of the important basic process claims can be sustained. Having been actively identified with the development of the art in America since 1882, and with the defense in recent important suits, he speaks with a conviction born of facts as found by an exhaustive study of the subject, and with the hope that it may be of some help to those debating what to do about the royalty question.

The American Sewage Disposal Company's case against the city of Pawtucket was adversely reported a few months ago in the United States Circuit Court.

The Cameron Septic Tank Company's claims against several municipalities are now being defended. It should be a source of gratification to the engineering profession at large that the city of Plainfield's example has not been followed. That municipality paid $4000 in acknowledgment of the validity of the Cameron patent rather than contest the same. It was considered cheaper to settle than to fight. But other places have a higher sense of responsibility than to pay out money on request, simply because somebody may have secured a patent unguaranteed by the Government, and whose validity can only be established by a test case in the courts.

DISCUSSION.

Kenneth Allen (Atlantic City, N. J.).—I have been very much interested in listening to Mr. Snow's paper. I do not know that I am particularly well qualified to discuss that portion respecting Atlantic City, for my work has been in a little different line there. It would seem from what Mr. Snow says that Mouras was, after all, the first one to use the septic tank; for while Alexander Müller used it in Saxony and Prussia prior to 1873, Mouras appears to have used it some twenty years prior to 1883 or 1882. I believe this use of it in Germany was for treating the effluent from beet-sugar factories, and not for sewage proper.

One interesting apparatus was that of Scott-Moncrieff, referred to by Mr. Snow, in which the septic sewage was put through a series of trays, the different bacteria developing in each and each one doing its part, with the fresh sewage going into the top tray and dropping through to the next, and so on through several shallow trays, the effluent coming out at the end of a few minutes from its entrance to the top tray, when it was purified. That was a very remarkable illustration,—not on a large scale but rather experimental in character.*

One point that I think has been until recently overlooked in the past is the precise quality of the effluent that should be secured. It has been generally assumed in planning a disposal plant that if you put in a certain number of grains of alum or lime, or if you apply a certain amount of sewage to a given area, you are going to get a certain result that will be satisfactory. Now there are a good many points that should be taken into consideration. Among them the kind or character of the stream that the effluent is to go into—whether there is a sufficient amount of dissolved oxygen in that stream. Also the character of the sewage. These two points in themselves make a great many combinations or conditions, so that special study is necessary for each case.

Bacterial treatment is no doubt the scientific treatment for sewage; at the same time, I think there are cases where sterilization is an aid for temporary purposes; for instance, in cases where we know the sewage contains pathogenic bacteria, and it is desired to eliminate these when the sewage goes into a stream used for drinking purposes. In that case, it seems to me, sterilization might be used temporarily, as a device which would accomplish that end, as it is used now for sterilization of storm-water on one or two of the small areas of the Croton watershed.

The Royal Commission's investigations are being looked for with a good deal of interest, of course. The reports up to the present time contain a great deal of matter, but unfortunately it is withheld so long that when it reaches the public it is not as new as desirable. They seem to rather favor the application of sewage to land; that is, if I understand it, they conclude that, taking all things into consideration—the cost, the area of land required, and the result secured—there is greater economy, as a rule, in England, in sewage farming than there is in special treatment. I think that is a question that must be studied for each case; much depends on the land required and its cost. The area required for irrigation is perhaps ten times that required for intermittent filtration; and that, perhaps ten times that required for the most efficient bacterial treatment. The experience with treatment on land—sewage farming—is of long standing, especially in England and in Europe generally; and as I do not suppose that much greater concentration of dose per acre is liable to be had in the future, the greater the concentration obtainable by bacterial treatment, the greater the advantage this kind of treatment will have over land treatment. Where the effluent is to be turned into a water that is subsequently to be used for drinking purposes, it seems to me that the treatment on land is somewhat safer. That is, if anything

* "Dr. Samuel Rideal, . . . who has examined the working of this system, after mentioning that the time taken for passage through nine trays was about eight minutes when observed, analyzed the effluent," and says: "The nitrate has developed with extraordinary rapidity and to an extent that exceeds any other known process."—*The Polytechnic*, Sept., 1899.

happened to interfere or interrupt intensified treatment, the results, it seems to me, might be more dangerous than in the case of land treatment.

Disposal into tide-water seems to be accepted now as the proper thing where the conditions justify it. In considering the problem in Baltimore some years ago the Commission recommended disposal into the Chesapeake Bay. After making float and tidal experiments to see what the dispersion would be, and after reconsidering the matter after the presentation of their first report, they reported a second time in confirmation of their first recommendations. The particular objection came from the people interested in the oyster business, which is there of such importance that it is not at all likely now that this plan will be carried out. The way it was looked at by the Commission was that if the sewage were emptied into the Chesapeake Bay many miles below the city and some two miles from shore, the large area of dispersion and the great area of water that would be available to take care of the sewage would prevent any unsatisfactory conditions, the only point in question being the contamination of the oyster beds. And it was considered that if the taking of oysters were prevented by law within a certain distance of the outfall, as Mr. Snow has recommended for Atlantic City, the possibility of contamination beyond that area would be so very slight as to be negligible. Dr. Brooks, of the Johns Hopkins University, looked at it in a different way. He considered that the bay being full of organic matter, this food for bacteria might promote their growth after being discharged into the bay, and that it was consequently impossible to tell to what extent they might develop and contaminate oysters further down the bay; although, as a matter of fact, the oysters are taken from near the shores, and the tendency of the sewage was to concentration in the channel. However that may be, the result was that there was so decided an opposition from the oyster interests that this project was abandoned.

The city is now in a position to go ahead with the work, and has an opportunity such as is seldom given to a municipality to put in a complete plant on a very large scale, and there seems no reason why it should not be very perfect in its way, for the reason that land in the vicinity is cheap,—much cheaper than in the vicinity of most large cities,—and that if filtration should be decided on, there is a great quantity of excellent coarse sand within a reasonable distance of the city.

The matter of bacterial treatment is so new that it is possible that its complete installation may be deferred here, but that system will probably be found in the end to have marked advantages over any other.

C. Hampson Jones (Baltimore, Md.).—Before attending the meeting I had no idea that I would be expected to speak, and I have been somewhat disturbed by the fact that I was informed after my arrival that I might be called upon. I tried, however, to pay strict attention to the lecture, and I am sure that I have profited very much by it. The subject, I am glad to say, is one that Baltimore is now taking up in real earnest, for the reason that we have just lately passed through a campaign in which we were successful in getting the loans for the purpose of establishing a sewerage system. The establishment of a sewerage system, of course, is independent of the ultimate disposal of the sewage. As to that point, I think I am perfectly safe in saying that we have only two propositions to consider: first, the irrigation system, about ten miles from the city; and the other

is the so-called septic treatment of the sewage. The first cost of disposal by the irrigation system is so great that it has been determined to first try the septic system. Not less than 20,000 acres, and in all probability nearly 40,000 acres, of land will be necessary for such an undertaking. Berlin at this time is using about 30,000 acres, and it has only been within the last year or two that it has been a fair investment, and that was because of the high-priced food due to the want of rain; that is, elsewhere than in filtration beds. We know very well that the septic treatment of sewage is perfectly successful in small localities, and we are watching with considerable interest the introduction of the septic tanks in Manchester, England, which is about the same size as Baltimore. In my own judgment, if a system is successful for small quantities of sewage, it certainly can be successful for no matter how large a plant by merely multiplying the unit of construction. Of course, I am particularly interested in what we are going to do in Baltimore, but in my judgment, for those towns or cities that have finally to dispose of the sewage into streams from which drinking-water is subsequently taken by cities lower down, there is no other system that is so safe as the septic system. Properly managed, they will do the work. Improperly managed, like everything else, they will not do the work; so that, after all, it is a matter of careful supervision of such systems.

R. H. Garrison (Vineland, N. J.).—This matter is in the hands of the Government at present, under the direction of Dr. Moore. You all know of his results with copper sulfate in reservoirs, and they are now experimenting with copper sulfate in connection with sewage purification. I have not studied over the test data yet, so I cannot tell much about the results, except that they are proving very successful as far as they have gone.

We have in use sand filtration and settling beds without septic tanks and discharge our effluent into potable water; and so far (previous to the use of copper sulfate) did not purify the effluent to the extent required. We are experimenting now to get something to help our beds obtain a high degree of purification without a septic tank.

I suppose Dr. Moore will make public his results in time; I think they are in a new line, but I am unable to tell you much about the results so far.

P. J. A. Maignen.—The paper is a great credit to the Club and to the author. I have never heard a paper so complete and full of facts. I should like to ask whether it is desirable to apply chemical treatment before or after septic action —of course, it cannot be applied before septic action, because it would prevent it, but I understand that the chemical treatment is to be applied to fresh sewage and not to stale sewage. I would also like to ask, what, in his experience, is the proper time required for the septic action to be complete? Some samples of sewage which I have examined after twenty-four hours and after six hours present characteristics that are entirely different. I think it would be desirable for students of the art of sewage treatment to have some advice as to the proper size of septic tanks. Is the cremation of sludge carried out at one of the plants referred to? Why were the crops discarded? What is considered the best practice in England now? When I was there I saw the use of manganate of soda and sulfuric acid, and later on iron and lime. What is the actual practice in London? And, finally, I would ask the author, who has described the processes which are apparently successful in every case and yet so different, what he

would recommend for a place in which there is neither a body of water to dilute and take away the sewage nor natural sand to filter it?

Mr. F. Herbert Snow.—In answer to the first question: Chemical treatment should be applied to sewage as a means of removing the suspended solids prior to the liquid going upon a filter, of whatever kind that filter may be, unless it is desired to get an absolutely sterile effluent from the plant; and if so, probably some electrical treatment would sterilize the effluent as well or as cheaply as any known process.

Second, regarding the optimum period of subjecting the sewage to septic treatment, the speaker knows of no authority on the subject. Among other things, it depends upon the quality of the sewage. In fact, in some sewer systems the sewage upon reaching the works has been so completely decomposed that it is useless to pass it through or expose it to any further degree of septic action. As a general rule, it is good practice to design for a twenty-four hour period. The fluctuations in the quantity and quality of the sewage should be kept in mind and arrangements should be made to admit of controlling the period. Whether it should be twelve hours or more must be determined by practical experience. So little is known about what constitutes the optimum period that every plant built must be considered in a sense an experimental plant.

Third, cremation of the sludge is not provided for in any plant described by the author. The Mansfield crematory is for garbage only. The advantage of having a crematory at the sewage works is apparent. The same set of men handle both, thereby effecting economy in management.

Fourth, the crops were abandoned at Brockton when the experiment was concluded. The trials were instituted in the beginning to learn to what extent crops would assist in the destruction of the sludge. It was found that cropping the beds was not the most efficient means of promoting the sludge disposal. The shade of the crops retarded the drying-out process and tended to create a pronounced odor.

Fifth, the process in London at the present consists in the precipitation of the suspended solids by the use of chemicals, mostly lime.

Sixth, in a case where there is no sea or sufficient body of water into which a clarified effluent may be discharged and no natural sand through which it may be filtered, the only method remaining, other than sewage farming, is some one of the accelerated processes of filtration.

In reference to Mr. Allen's discussion, it is true that Mouras's use of the septic tank antedated that of Dr. Müller, but Müller published his view years before Mouras's tank became known. While it is also true that Muller's process was intended for the treatment of beet-sugar works, as Mr. Allen says, it is still further true that in the specification of his patent, 1878, Dr. Müller emphasized the fact that the process was intended to be applied to the disposal of town sewage. With respect to the Scott-Moncrieff process of rapid filtration to which Mr. Allen referred, it has not yet been demonstrated in practice that sewage can be passed through any zone or cycle of zones of bacterial activity and in a few minutes be purified by such agency or any other agency; but there is no doubt that along the lines of rapid aeration advancement is to be made. I agree with Mr. Allen that the question of the quality of the ffluent necessary in any particular plant should be carefully considered. The

importance of this point has not been thoroughly grasped by engineers. The character of the stream receiving an effluent ought to be taken into consideration in solving a problem of disposal. Atlantic City is a good illustration of this fact. Regarding sterilization, it may be true that there are some cases in which this end should be solved, but the speaker has never met one, and he believes they are so few that the subject is not worth considering at this period in the development of the art of sewage treatment. There is no question about there being what may be called a legal pollution which results from the mere existence of a city on the banks of a stream or the borders of a body of water. Even if a city purifies its sewage according to the best practical method known today, the effluent from the treatment will contain bacteria and organic matter of a polluting character. Besides this contamination, there is the natural surface wash from the roofs, yards, and gutters, which cannot be prevented, and sensibly pollutes any river into which it may go, so that the down-stream proprietor who wishes to use that water for drinking purposes does so at his own risk if he does not take the precaution of filtering it. So we have two necessities: first, the minimizing by sewage treatment of the pollution by the up-stream proprietor; second, the filtering of the water by the down-stream proprietor.

Regarding the position of the Local Government Board of England in reference to land treatment or sewage farming, to which Mr. Allen referred, it would seem as though adherence to this method were necessary for two reasons: first, because it is efficacious and the best safeguard in that country; and second, because, being an ancient legacy, it is impracticable to abandon the system. There would be no adequate return and the adoption of other methods would be excessively expensive.

Mr. Allen's reference to oysters and clams affords an opportunity to call attention to the necessity for interstate regulation of the industry. Several years ago in Atlantic City it was the custom to dig clams in the Thoroughfare in the vicinity of several sewer outlets. These clams were sold in the city. An epidemic of typhoid fever occurred. Investigation served to prove that polluted clams and oysters were the cause. Therefore the Board of Health took measures to prevent traffic in Thoroughfare shellfish. The local oystermen at first remonstrated at this so-called "unwarrantable interference," but public sentiment, having been enlightened, demanded vigorous measures, and the merchants found that only through support of the Board of Health efforts could their business be successfully maintained. One merchant only defied the Board, and today he is carrying on his business. He purchases clams and oysters brought in from unpolluted sources and lays them down in a float located within three hundred feet of a sewer. Here they stay pending shipment. As would be expected, the clams and oysters are polluted by retention in that float. They are found on examination to contain intestinal organisms in very large numbers, some of which undoubtedly may be pathogenic. At any rate, the food is unsuitable for human beings; but this does not prevent him from shipping the shellfish out of the State and beyond the jurisdiction of the New Jersey authorities. They may be sold in Philadelphia, New York, and elsewhere. There are several million clams thus shipped annually to an unsuspecting public. No better illustration of the necessity for interstate regulation of this industry should be needed.

ABSTRACT OF MINUTES OF THE CLUB.

Regular Meeting, March 18, 1905.—President Comfort in the chair. One hundred and twenty members and visitors present.

Prof. Rondinella announced the death of Mr. Edward Longstreth, active member, on February 24th, and that of Mr. William Sellers, formerly a member and past President, on January 24th.

Mr. Walter Loring Webb read a paper on "Reinforced Concrete—Some of Its Principles, with Practical Illustrations."

Mr. Coles, of the General Electric Company, explained a method of changing alternating current to direct current by means of a "mercury vapor rectifier," and demonstrated the method by means of an apparatus.

Business Meeting, April 1, 1905.—President Comfort in the chair. Eighty-two members and visitors present.

Dr. Henry Leffmann read a paper on "Sanitation in Office-buildings."

Prof. L. F. Rondinella read a paper on "The Reproduction of Drawings of Great Length and Number."

The Tellers announced the election of W. W. Nichols and Willard T. Sears to active membership; John W. F. Blizard, Franklin S. Chambers, Samuel J. Dickey, John A. Frick, Yazujian M. Karekin, and Sidney B. Strouse to junior membership, and Richard Y. Filbert and John S. B. Nagle to associate membership.

Regular Meeting, April 15, 1905.—President Comfort in the chair. Eighty-six members and visitors present.

Mr. Foster, as Chairman of the Philadelphia Branch of the American Institute of Electrical Engineers, presented to the Club a new screen for the lantern, as an evidence of their appreciation in being allowed the use of the Club House for their monthly meetings. Mr. Trautwine moved a vote of thanks for this gift, and it was unanimously carried.

Dr. Wm. McClellan read a paper on "The Electrical Engineer in Heavy Traction Work."

Business Meeting, May 6, 1905.—President Comfort in the chair. Seventy members and visitors present.

Dr. E. F. Northrup read a paper on "Stereoscopic Vision Applied to Surveying."

Mr. Luthar D. Lovekin read a paper on "Recent Developments in Expanding Machinery."

The Tellers announced that William Herbert Gibson, Louis H. Losse, and Joseph Aiken Simons were elected to junior membership, and that Henry Longcope was elected to associate membership.

Regular Meeting, May 20, 1905.—President Comfort in the chair. Eighty members and visitors present.

Mr. F. Herbert Snow read a paper on "Bacteriological Treatment of Sewage."

ABSTRACT OF MINUTES OF THE BOARD OF DIRECTORS.

Regular Meeting, March 18, 1905.—Present: President Comfort, Vice-President McBride, Directors Dallett, Davis, Quimby, Loomis, and Devereux, the Treasurer and the Secretary.

The President reported that he had received invitations to attend banquets from the Boston Society of Civil Engineers and the Engineers' Club of Cleveland and that he had sent regrets for the same.

The Treasurer's report, dated March 13th, was read and accepted as follows:

Balance, January 31, 1905,		$2993.54
February receipts,		608.00
		$3601.54
February disbursements,		561.51
		$3040.03
On hand and in Girard Trust Co.,	$2461.60	
In West End Trust Co.,	578.43	$3040.03

The Finance Committee reported the approval of numerous bills.

On motion the Regular Meeting of April 1st was designated as a Business Meeting.

It was moved and carried that the lease of the Club House at $105 per month be accepted, and that the lease should be signed by the President and Treasurer.

A letter was read from the Public Education Association of Philadelphia, requesting an indorsement by the Club of the Scott Bill, now pending before the legislature at Harrisburg. The Secretary was instructed to write to that Association, "that since the restrictions of the By-Laws of the Engineers' Club would forbid that such a matter be brought before the Club until the meeting of April 1st, and since such action, if taken, would be too late, the Board of Directors considered that it would be impossible to do anything in the matter."

It was moved and carried that the committee on the "Relations of the Engineering Profession to the Public" be dropped.

It was moved and carried that the acceptance by the Club of a copy of "Cement and Concrete," by L. C. Sabin, be referred to the Publication Committee with power to act.

It was moved and carried that the Secretary of the State Board of Health be notified that we could probably dispose of 200 copies of the report of "The Operations of the State Board of Health in the Suppression of the Typhoid Fever Epidemic at Butler, Pa.," also that notice be included in the notices sent to mem-

bers that such copies are obtainable at the Club House, or that copies will be sent to them upon receipt of the postage.

It was moved and carried that the application of the Business and Professional Club for the use of the Club House on April 4th be referred to the House Committee with power to act.

An offer having been received from Mr. Geo. Burnham, Jr., to donate to the Club some unbound transactions of the American Society of Civil Engineers, it was decided to accept such copies as might be needed to complete any deficiencies in the Club files, otherwise to decline the offer with thanks.

A letter having been received from Mr. Ed. Caldwell, regarding miscellaneous copies of engineering periodicals, accompanied by an offer to purchase the same for $50, the matter was left to the Library Committee with power to act.

Regular Meeting, April 15, 1905.—Present: President Comfort, Vice-Presidents McBride and King, Directors Davis, Easby, Loomis, Dallett, and Quimby, the Treasurer and the Secretary.

The Treasurer's report, dated April 11th, was read and accepted as follows

Balance, February 28th,		$3040.03
March receipts,		674.41
		$3714.44
March disbursements,		847.87
		$2866.57
On hand and in Girard Trust Co.,	$2288.14	
In West End Trust Co.,	578.43	$2866.57

It was moved and carried that when books are sent to the Club for the purpose of having them reviewed in the Club's "Proceedings" the policy of accepting the books and publishing a review of them shall be left to the Publication Committee with power to act.

It was moved and carried that the Regular Meeting of May 6th be considered a Business Meeting.

The Finance Committee reported the approval of sundry bills.

The Advertising Committee reported very successful progress in obtaining the renewal of old subscriptions, and also in obtaining new subscriptions for the Club Directory.

It was moved and carried that the next meeting of the Board be held at 7 P. M.

Regular Meeting, May 20, 1905.—Present: President Comfort, Directors Davis, Quimby, and Devereux, the Treasurer and the Secretary.

Messrs. Loomis and Easby sent letters of regret regarding their absences. There being no quorum, the meeting adjourned.

ADDITIONS TO THE GENERAL LIBRARY.

From Edward Orton, State Geologist.

Geological Survey of Ohio. Fourth Series Bulletin.

From American Society for Testing Materials.

Proceedings of Seventh Annual Meeting. Volume IV.

From Wm. H. Taft, Secretary of War.

Report of Tests of Metals, etc.

From Bureau of Education.

Report of the Commissioner of Education for 1903. Volumes I and II.

PROCEEDINGS

OF

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PAPER NO. 1012.

THE MICROSCOPIC STRUCTURE OF BUILDING STONES.

HENRY LEFFMANN.

Read September 16, 1905.

IN a comprehensive sense, rock is any natural mineral substance, but this will include water, sand, petroleum, coal and natural gas, materials that would not in ordinary language be termed rocks. Geologically, a rock is a mineral aggregate, forming part of the earth's crust. This paper is concerned with a still narrower feature, namely, those minerals which are prepared by mechanical means for constructive purposes. It is almost never possible to draw a sharp line in classification, and it is necessary, therefore, to include some materials, partly artificial, which are substitutes for, or accessories to, natural materials. Among these are slag, concrete and brick.

The rocks and rock-substitutes used in engineering construction are selected under rules that differ with the conditions.

ORNAMENTAL CHARACTER is usually of great importance, but high ornamentation and refined architectural effects may be so incongruous as to be hideous. Designs adapted for a church, bank, or college would be wholly out of taste if used for a mill, a prison, or a fort. In the vicinity of a city the engineer will construct a bridge-pier of dressed stone, while in remote districts coarser work will be appropriate.

DURABILITY is of prime importance, and with it locality and other

features have determining influences. In the first place, durability is much coördinated with climate. In places in which temperatures range within wide limits, stone is apt to suffer much more than where the temperature range is narrow. This is especially true if the limits of temperature-change are respectively well above and well below the freezing-point of water. A stone that would be unchanged for many years in Porto Rico may be soon injured in Maine. Even a narrow range of temperature-change may act injuriously if extreme as to heat or cold. Moisture has considerable influence, especially as to the manner of its precipitation. In many localities, rain beats commonly in certain directions. Constructions facing these directions will be exposed to the mechanical action of the rain drops, and to the partly mechanical, partly chemical action of the running water.

The abnormal conditions in modern cities have a high destructive action on building material. The use of coal increases very much the proportion of carbonic acid in the atmosphere, and adds notable amounts of sulfurous and sulfuric acids. These acids, caught by the rain or fog, are deposited on the surface of the stone and produce corrosion. The solid particles of the smoke, partly carbon, partly the fine gritty material of the ash, are blown against the stone and act with more or less force as abrasive materials.

The carbon deposit may act as a protective, but it is at great sacrifice of artistic features. These actions of furnace emanations will be exhibited unequally on account of the location of the offending plants. Thus, in Philadelphia, the most serious smoke-nuisances are from the northwest section: the yards of the Pennsylvania Railroad, the Baldwin and Bement works, and that somewhat distant but hideous offender, the Midvale works. It will be noticed, therefore, that the discoloration of buildings in the eastern center of the city is on the side facing northwest. The columns of the Drexel building show this. For a long time the statue of Washington at Independence Hall showed the left eye much discolored with soot, while the right eye, probably protected by the nose, was but little stained. I had the honor of presenting to the Club about a year ago a dissertation on Washington, and I think it would amply appear from the facts of his life that it was not easy to shut his eye up, but Philadelphia seems to have nearly done it. In consequence of these injurious influences, some building materials that last a long while in rural districts succumb rapidly in manufacturing localities.

Occasionally specific chemical changes are produced by direct

action of oxygen causing discoloration and dilapidation. A rock may contain pyrites, in small amount, which may be regarded as of little moment, but when the dressed surface is exposed to the air, the pyrites may be converted into iron oxid, and this being washed out by the rain or dissolved by acids in the air, will result in pitting and a stain of iron rust below the point of solution.

Where the air carries abrasive materials, as near the sea, much mechanical injury may be done. In this manner some of the Egyptian obelisks which are uninfluenced by the general conditions of climate have been badly scarred on the surfaces that face sand-laden winds.

Resistance to Crushing and Fracture are equally important. The coefficients of these factors may be affected by the conditions that have been mentioned as affecting durability. They, as well as the general coefficient of durability, may be much affected by the condition of the rock in the quarry and by the arrangement of the block with reference to natural stratification lines. It is obvious that, other things being equal, a rock that has marked stratification planes is likely to suffer most from atmospheric action if the block is placed so as to expose the edges of the planes to the air.

In the construction of pavements, high power of resistance to abrasion by hard and heavy bodies is necessary. Ordinarily, the question of the corrosive or abrasive action of common dust or streams of water is not important, but in the asphaltic cement pavements so common in American cities, the nature of the asphalt will determine the durability to large degree. Thus, the Trinidad asphalt contains a considerable amount of non-bituminous organic matter which is easily oxidized and renders the asphaltic mixture more liable to rot in gutters than the similar mixture made with Bermudez asphalt, which contains but little non-bituminous matter.

The applicability of the different building materials in general use has been determined by experience. Engineers, as a rule, are indifferent to the questions of chemical composition or minute structure. Given the conditions under which the stone is to be used the selection is usually made without hesitation. This empiric method appears in many manufacturing operations, yet the tendency of intelligent workers is to substitute, as far as possible, scientific knowledge for practical experience. The knowledge that a certain material resists well the action of air, while another, possibly very similar in general appearance, does not resist; may be in general sufficient for

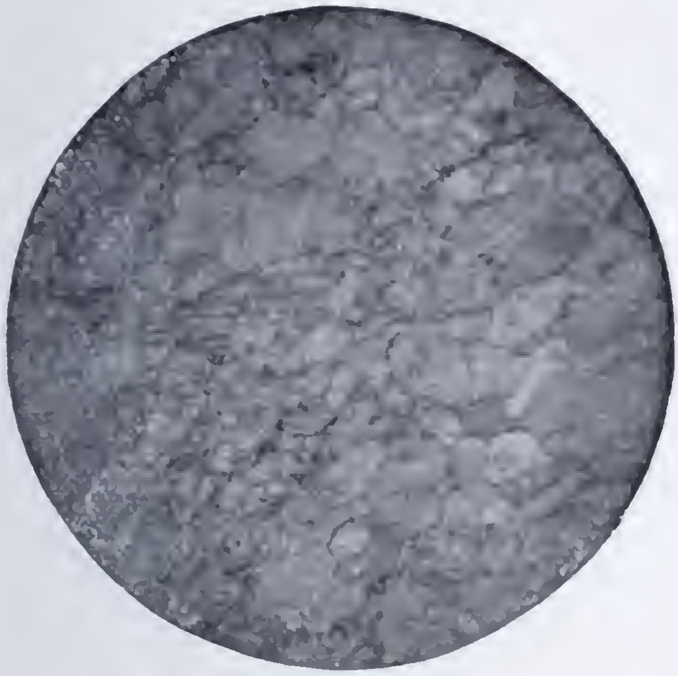
practical purposes; but to determine why such difference exists is an inquiry that cannot be avoided. Such an inquiry must be carried out in several directions. Among the most important of these are chemical composition and physical structure. The study of the former has been pursued for over a century and a large amount of information is at hand. Unfortunately, as so often happens in the progress of a science, many of the earlier acquired data in mineralogic chemistry must now be rejected on account of errors in analysis. Within the past decade, great advance has been made in the methods of analysing minerals. For much of this advance credit is due to the laboratory of the U. S. Geologic Survey, particularly to Hillebrand. It has been shown that important ingredients have been entirely overlooked. Titanium has been included with silicon; some of the rare elements have been included with calcium or aluminum; small amounts of barium and strontium have been overlooked.

The following analyses reported by Hillebrand (*Jour. Amer. Chem. Soc.*, vol. xvi, 1894, p. 90) are from the same rock, the difference in the constituents being due to the improved methods adopted in making the later analysis:

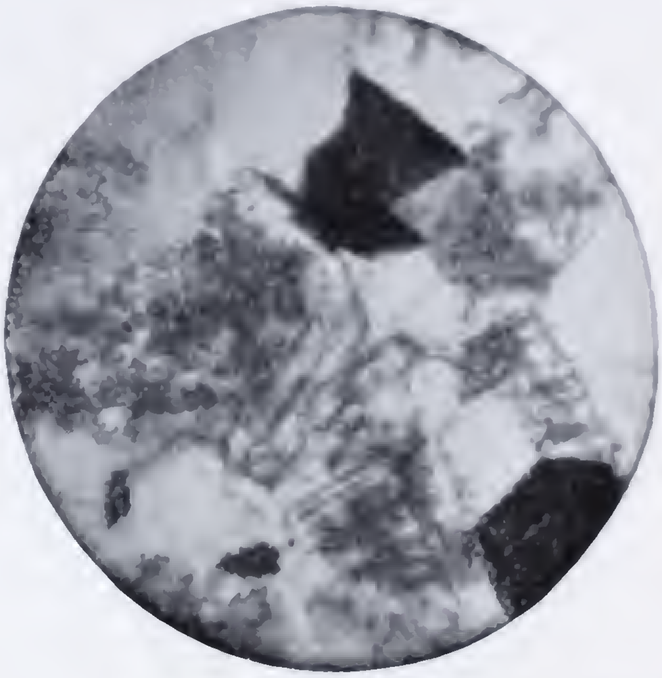
	Old Analysis.	New Analysis.
Silicon dioxid	54.42	53.70
Titanium dioxid	...	1.92
Aluminum sesquioxid	13.37	11.16
Chromic oxid	...	0.04
Ferric oxid	0.61	3.10
Ferrous oxid	3.52	1.21
Manganous oxid	...	0.04
Calcium oxid	4.38	3.46
Strontium oxid	...	0.19
Barium oxid	...	0.62
Magnesium oxid	6.37	6.44
Potassium oxid	10.73	11.16
Sodium oxid	1.60	1.67
Lithium oxid	trace	trace
Carbon dioxid	1.82	none
Phosphoric oxid	...	1.75
Sulfur teroxid	...	0.06
Fluorin	...	0.44
Chlorin	...	0.03
Water, below 110° C	...	6.80
" above 110° C	2.76	2.61

The figures do not add to 100, but this is generally the case in rock analysis. An allowance must be made for the oxygen-equivalent of

the fluorin, which will bring the total closer to 100. Hillebrand says that the difference observed as regards the relative proportion of ferrous and ferric oxids is probably due to accidental transposition of

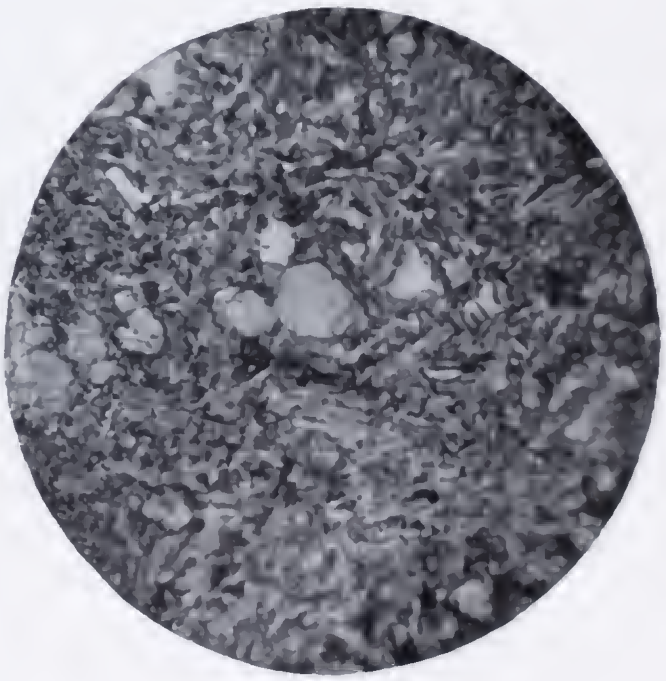


MARBLE. × 30.



GRANITE. × 20. (WANAMAKER BUILDING.) ORDINARY LIGHT.

GRANITE. × 20. (WANAMAKER BUILDING.) POLARIZED LIGHT.



DOLERITE. × 40.

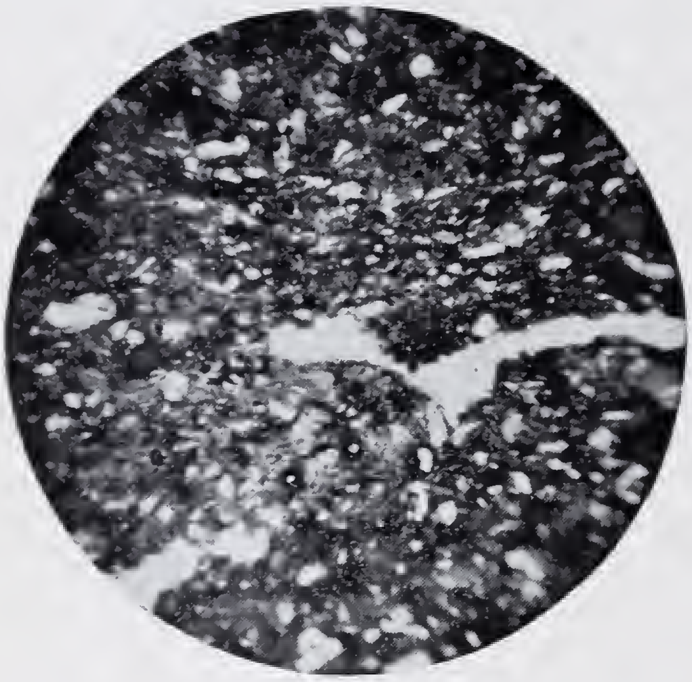
figures in the first analysis, as repeated tests have shown that the rock is richer in ferric than ferrous compounds.

Chemical analysis, however minute and accurate, will furnish but little information on the engineering value of rocks. I had occasion

to point out some years ago, in a verbal communication to this Club, that the same holds in regard to the ultimate analysis of clays. With both clays and rocks, proximate analyses must be made. By proximate analysis is meant the recognition of the distinct compounds

LAVA. × 65.

OBSIDIAN. × 60.



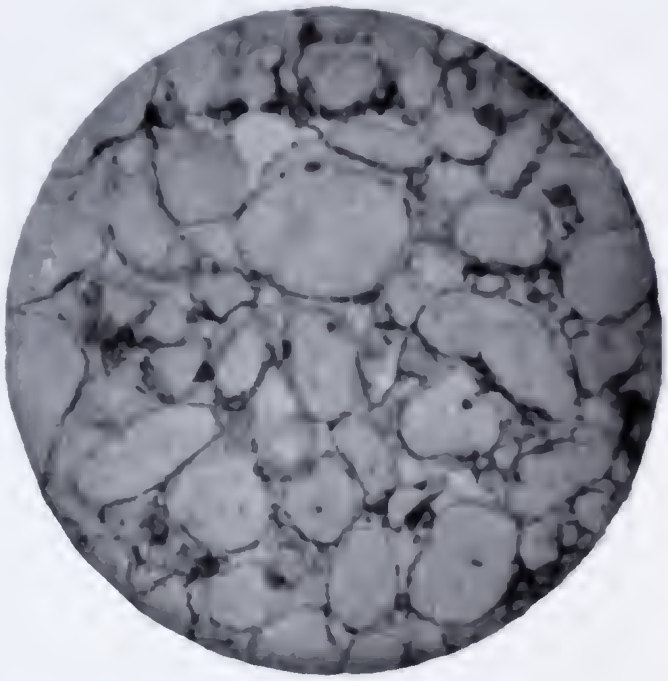
TERRA COTTA. × 25.

HORNBLENDE SCHIST. × 25.

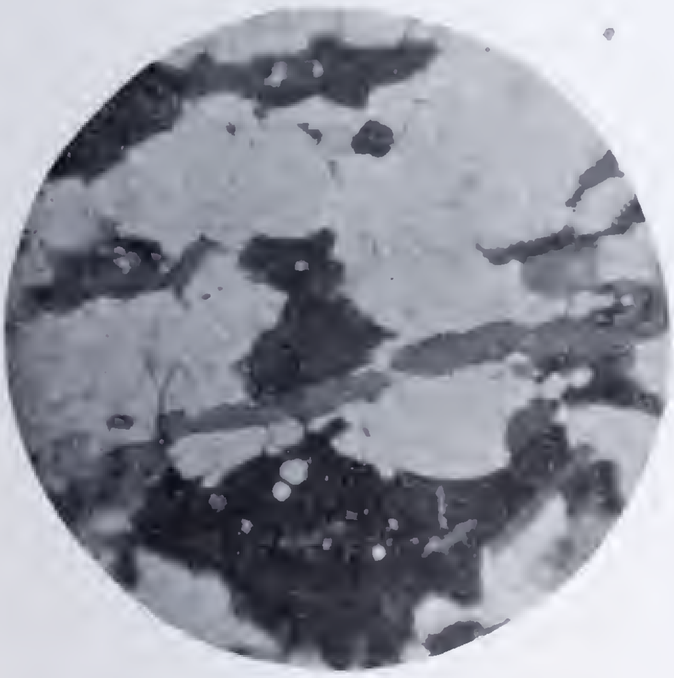
that the rock or clay contains. Water, for instance, is composed of hydrogen and oxygen. No separation can be made except into these elements. A given amount is either water, as such, or it is hydrogen and oxygen. Strychnin, though more complex in its molecular struc-

ture than water, is also made up of but one grouping. An analysis of it merely shows four elements,—carbon, hydrogen, nitrogen, and oxygen. Flour consists of several distinct compounds, such as the gluten, starch and mineral matters. A mere statement of the total

SYENITE. × 25.



SANDSTONE. × 25.



GNEISS. × 25. ORDINARY LIGHT.

GNEISS. × 25. POLARIZED LIGHT.

amount of each element (carbon, hydrogen, etc.) in a sample of flour would be of no practical use. The same is true of rocks, except as to some of the simplest, such as gypsum. They are aggregates of minerals each of which has characteristic properties. It is impos-

sible, however, in most cases, to separate the minerals in such a manner as to submit each to analysis. Fortunately, where chemistry fails the microscope is available. Within a comparatively short time, a new science has been developed, usually termed Petrology, the study of rock fragments, in contrast to Geology, the study of rock masses, and Mineralogy, the study of the individual minerals.

In the field that I have chosen to discuss to-night, the relation between laboratory observation and practical application is still but slightly developed. I will not be able to present methods by which the problems of durability and strength can be solved without appeal to practical methods, but I can indicate the general nature of the results that have been obtained by careful and somewhat laborious study on the part of specialists, and incidentally show some striking and interesting features.

The microscope is in some respects the most valuable and the most efficient instrument of human invention. Its history dates from the latter part of the seventeenth century, but the development of its usefulness in many fields of science is a matter of less than half a century. It is not opportune here to discuss the construction of the compound microscope and its accessories, but I think it necessary to say in passing that the popular notion that the microscope is merely a means of magnifying objects is an incomplete view of its usefulness. The most recent advances in microscopic technic have not been in the way of increasing magnification, but in increasing definition. Lenses were made in abundance before the first half of the nineteenth century that possessed as high magnifying power as those now made. The great modern advances in the microscope have been in differentiation of the field, that is, increasing the clearness with which the different portions of the field are seen and in indicating, by accessory methods, differences that are not visible under simple magnification. Thus, in the important departments of pathology and bacteriology, mere magnification has not been the basis of the great developments that have been attained. The introduction of staining agents and the improvement of culture methods have been important aids.

In the study of minerals, these methods are inapplicable except that some analogy to staining is found in the use of corrosive chemicals for etching the surfaces of minerals and metals. In petrology the application of polarized light has been of the highest advantage. Indeed, much of the information now at hand would be unattainable without it. Polarized light is a modified form of common light espe-

cially sensitive to structural conditions, revealing them when ordinary methods of examination show no peculiarity. It is, among other features, sensitive to molecular stresses and will show the location and extent of such stresses clearly.

Recently a new method of research into structure has been developed. It has long been known that ordinary light contains rays that are not appreciable to the human eye, and that these rays do not pass through some substances that are transparent to the visible rays. These peculiar rays are termed "ultra-violet." They do not pass readily through glass, but freely through quartz. A German scientist has lately devised an apparatus for utilizing these ultra-violet rays, using quartz lenses and prisms, and, as the rays are invisible to the human eye, receiving the image on a photographic plate, from which, by the usual methods of development, the visible image may be obtained. This line of research has just begun; in time it will yield valuable results. The contradiction of terms that arises in connection with this work is interesting and even amusing. The ultra-violet rays are invisible, glass is opaque to them and some other substances modify them similarly to the way in which colored glasses modify common light. It is therefore possible to work with "invisible light," using "opaque transparencies" and "colorless colors."

The microscopic structure of rocks is studied in sections ground thin enough to be transparent. Very few minerals are known that cannot be thus prepared. Some compounds of iron and manganese are opaque in the thinnest attainable form. These often occur in small particles scattered through the rock, appearing as opaque dots. Petrology is a modern and undeveloped science. The materials for study and classification are numerous; the workers are comparatively few, hence we do not find the development of an old and much studied science. The classifications are provisional. The aid that the doctrine of evolution has given to botany and zoölogy is not available in petrology. While there is a limited relation of descent between rocks, it is not of the nature of biological descent, but more analogous to the pathological changes occurring in tissues. In many cases, rocks undergo alterations in their inmost structure by which chemical and physical characters are much changed. Such processes are extremely slow and are traced more by their results than by the actual processes. Broad distinctions are, however, easily recognized in the study of the different rocks. It is seen that many have been produced by the cooling of a liquid mass; that others are the results of sedi-

mentation from water, with no special modification except moderate compacting by the pressure of the upper layers on the lower. Other rocks again are collections of wind-borne materials subsequently compacted by interstitial cementing substances. The sedimentary and wind-formed rocks may be subjected to great heat or pressure by which profound changes, chemical and physical, will be wrought in their composition, and they will then bear some relation to the fused rocks, but will not be identical with them. The characteristics of the fused rocks will be much modified by the degree of fusion and the rate and circumstances of cooling. Imperfect fusion,—that is, when some of the constituent minerals (proximate constituents) have not been melted, will give rise to different structure from that which will obtain when complete fusion has occurred. The conditions of cooling, whether slow or rapid, whether under great pressure, or without appreciable pressure, will make the same materials exhibit different structures.

One of the simplest classifications is that of Merrill (*Rocks, Rock-Weathering and Soils*) into *Igneous, Aqueous, Eolian* and *Metamorphic,* corresponding to the definitions given above. Some writers divide more minutely. Thus, Harker (*Petrology for Students*) makes three classes of the igneous rocks based on the conditions of cooling as demonstrated by the structure, as follows: *Plutonic rocks,* cooled under great pressure at considerable depths, *Intrusive rocks,* met with in the form of dykes and masses of not very large size, cooled slowly and under moderate pressure. *Volcanic rocks* which have cooled rapidly under low pressure. The latter include the lavas.

All igneous rocks may by natural conditions be converted into fragments and be formed again, by the action of water or wind, into rocks of the sedimentary or eolian type, and these, by heat or pressure or both, be metamorphosed. As the duration of geological time is enormous in comparison with our human standards, the vicissitudes to which any given mineral may be subjected will be numerous, and, therefore, many varieties of rocks will be found, and rocks of general similarity in different parts of the world will exhibit considerable differences when studied in microscopic detail.

Among the characteristic features of rocks are the nature and extent of the crystallization, the nature of the cementing material, if any is present, the existence of cavities, and of particles of difficultly fusible substances, such as iron oxid and manganese oxid. When complete fusion occurs, the subsequent cooling may result in the crystalliza-

tion of some of the constituents, while others solidify as a nearly structureless (glassy) mass. In some cases more than one crystallization occurs,—that is, some constituents separate at a later period. It has long been known, from laboratory experiments, that the size and distinctness of crystals are directly proportional to the slowness of their formation. Hence, lavas show much uncrystallized material and many minute crystals, these often being arranged in lines, indicating that after they have been formed, the still viscous matrix has flowed in a definite direction. The true granites, which are igneous rocks, show no non-crystalline matrix. The whole field of the section is occupied by crystals more or less perfectly formed. To such, the scientific term "holocrystalline" is applied.

The sedimentary and eolian rocks are made up of fragments of differing sizes, and, if these have not been subjected to powerful compacting influences, the rock will not form a coherent mass. The deposit, therefore, will be a rock geologically but not technologically. Of this type are sand hills, and beaches, infusorial earths, gravel banks and clay banks. Sand, it must be noted, though usually containing silica (silicon dioxid) as its principal constituent, often contains many other minerals, and, sometimes, as in the case of coral sand, is almost wholly calcium carbonate. By the introduction of cementing material, loose fragments may be converted into a compact and cohesive mass. The cementing material may be either introduced from without,—that is, infiltrated into the stone,—or it may be developed by changes in the constituent masses themselves. Among the common cementing materials are clays, calcium carbonate (carbonate of lime), iron oxids and bituminous matters. Sometimes these, the cementing materials, do not entirely fill the interstices of the stone, and the spaces may, at a later period, be filled with other material, or, being impregnated with water, which is alternately frozen and melted, the stone will be broken down. Cementing material, such as iron oxid, that resists the action of ordinary air, may be dissolved by air charged with corrosive vapors, and thus a sandstone that serves excellently as a building material in rural districts will succumb rapidly in the air of a large city, becoming stained superficially and crumbling.

The harder stones generally included by engineers under the name "granite" are all mixtures of complex silicates. Many forms are recognized by petrologists. It has, indeed, happened more than once that a stone which is unhesitatingly designated by the archi-

tect as a granite, is not so called by a petrologist. Some years ago a suit at law grew out of a difference of opinion on the classification of a building stone which had been offered under specifications requiring granite. The stone offered by the contractor was rejected by the engineer, not on account of inferior quality but on the technical definition. Much expert testimony was taken on the subject. I might enter here upon a digression on the "the little joker" which often appears in specifications, and operates to the prejudice of bidders and contractors. Under such a specification as "Maine granite or other stone satisfactory to the supervising architect," "good clay satisfactory to the engineer," a pretty wide opportunity for favoritism is given. Some years ago the paving specifications of Philadelphia contained a clause requiring "Trinidad asphalt or asphalt of equal quality," and by a ruling that no other asphalt is of equal quality the monopoly of the work was assured to a certain company.

The selection of stone best adapted to conditions is often a difficult matter, and is not always accomplished. When great weight is not to be sustained, or severe atmospheric action encountered, a lighter or softer stone may be used with economy, especially if much carving is to be done; but it must not be overlooked that elaborate carving will expose the stone to more corrosion than when the surface is flat, not only because lodgment of acid waters is aided, but the delicate projections are easily broken and the incisions into the face of the stone expose the less resisting structures. Many rocks bear some resemblance to the flesh of animals. When the stone is removed from the quarry a slight consolidation or hardening of the outer layer of the block occurs, due partly to evaporation, partly to oxidation. This forms a protecting skin, but it is found by experience that if this layer be broken, the exposed portions do not harden to the same extent. It must also be borne in mind that in many places, especially near the sea, the high parts of buildings are exposed to mechanical abrasion. Merrill (*Stones for Building and Decoration*) states that one of the most eminent of American architects has built a structure of much artistic merit in which the walls are finished in massive granite, but window-sills, caps, cornices and other decorative parts, liable to weathering, are of soft and friable material. At Washington, the Executive Mansion and portions of the Patent Office and Capitol are of a sandstone so poor in resistance to atmospheric influences that they have to be painted occasionally. The Washington Monument on the Potomac, according to the same authority, is built up-

side down and wrong side out. The most resistant stone is on the inside of the upper part. In Philadelphia the sealing of brownstone and serpentine is often noticeable. I recall the disintegration of the large brownstone bases of the pillars of the Cathedral at Logan Square, some years ago.

The classification of rocks is based upon a recognition of their prevailing constituents. With a few exceptions, unimportant here, any mineral may occur in any rock. Some terms in Geology have been misleading in this relation. The names "Carboniferous," "Cretaceous," applied to periods of geological time, have led many to suppose that all the coal was formed at the one time and all calcium carbonate deposits at the other time. As a matter of fact, coal formation has occurred at many periods and is occurring now. Natural graphite is merely a very old coal. The coal of the northwest United States, which is more nearly allied to wood than is the coal of this section, is the result of later actions.

In the microscopic study of building stones, much variety of detail is encountered. Besides the dominating minerals which give the stone its position in classification, and determine, mainly, its engineering value, accessory minerals are found which often affect the decorative value and durability, increasing or diminishing these. Among these accessory materials, which generally occur in small scattered crystalline masses, are to be noted: pyrites (iron sulfid); magnetite and hematite (iron oxid); chromite (iron-chromium oxid); menaccanite (iron titanate); apatite (calcium phosphate). These materials may, however, of themselves form rock masses, and such deposits occur in many parts of the world.

An interesting feature, that can here be merely given passing allusion, is that of inclosures in minerals. Minute cavities occur which may contain solids or liquids entirely different in composition from the mineral itself. Quartz shows this feature often. The liquid is sometimes water, sometimes carbon dioxid liquefied by the pressure. Crystals are sometimes found in the cavities. In other cases a special crystallization is developed within the mineral, the crystals being in direct contact with, and penetrating, the substance of the host. Cases are often noted in which some of the less fusible minerals, such as pyrites and magnetite, resting in a viscous stream of rock, have checked and diverted the current, giving rise to deformation. This effect may be produced without fusion, when the rock is subjected to great pressure, by which it flows without liquefying, as does a

glacier. The deformation produced by the more resistant particles may result in the formation of cavities which are after filled with other minerals, such as quartz or calcium carbonate.

The minerals contained in rocks are often classified as primary and secondary. The former term includes those that were originally in the rock, the latter the products of alterations. As stated earlier in the paper, these alterations may take place while the rock is in a mass and be independent of artificial conditions or weathering. The individual minerals that occur in rocks are numerous, and it would lead much too far afield to name all of them. I can only speak of the more important and even of these but briefly. The chemical composition of most of these is complex. Silicon is to the mineral world what carbon is to the organic, hence many forms of silicates are found. The question is still further complicated by the fact that several elements—such as iron, aluminum, calcium, magnesium, sodium, and potassium—can replace each other partially or wholly, thus giving rise to intermediate compounds the classification of which is difficult.

Among the important primary materials are *quartz, feldspars, hornblendes, pyroxenes* and *micas.*

Quartz is silicon dioxid, SiO_2; the others are silicates.

Feldspars are aluminum silicates associated with potassium, sodium, or calcium silicates. The most important is *orthoclase,* potassium aluminum silicate, by the decomposition of which the purer forms of clay are produced, and from which the potassium compounds so necessary for land plants are obtained.

Hornblendes are principally calcium and magnesium silicates, with more or less iron. One division, to which hornblende proper belongs, contains notable amounts of aluminum and iron.

Pyroxenes are iron-magnesium silicates, with some aluminum and calcium silicates. They are, therefore, similar in composition to hornblendes, but are distinguished by physical characters, especially crystallization, as indicated in thin sections.

Micas are similar in chemical composition to the feldspars, but, as is well known, are characterized by the easy cleavage in one direction. The colorless micas are principally potassium aluminum silicate. The black mica contains iron, aluminum and magnesium silicates.

With these general explanations, it will be possible to take up some specific definitions, according to petrologists. I follow those of Harker (*Petrology for Students*), but each author has his own classification

in a measure, and all the suggestions are provisional. It will be noted that the ultimate chemical composition is not regarded.

Granite is of igneous origin, containing quartz, feldspar and some iron magnesian silicate. All the ingredients are distinctly crystallized. Accessory minerals are often present, and the quartz is apt to contain liquid inclusions.

Syenite is of igneous origin and consists of feldspars and iron magnesian silicate, with little or no quartz.

Diorite is igneous and contains hornblende and feldspar.

Basalt is a lava in which feldspars are abundant.

Marble and *limestone* are sedimentary rocks, principally calcium carbonate. The colors are due to accessory materials. The dark limestones contain carbon particles, the brown contain iron carbonate.

Dolomite is a combination of calcium carbonate and magnesium carbonate. It is somewhat more resistant to the action of acids than ordinary limestone and marble.

Sandstone is composed of quartz grains, cemented by infiltration of silica, iron oxid, calcium carbonate or bituminous matter. The sandstones infiltrated with silica are the most resisting.

Serpentine is a hydrated magnesium silicate, but is rarely found pure. Among the accessory materials are iron oxid, pyrites, and calcium carbonate, these greatly affect its durability.

Gypsum is hydrated calcium sulfate. It is too soft for ordinary building purposes, but is useful for indoor decoration. The finer quality is *alabaster*.

Of the commonly used artificial stones, slag is analogous to the volcanic rocks; cement to the sedimentary; brick and terra cotta to the metamorphic. The strength of any rock, particularly its resistance to abrasion and impact, will be largely dependent on the slowness with which it has been formed. Rapid formation produces weak structure; rapid cooling prevents proper annealing, producing brittleness. This is well illustrated in the making of glassware. If the mass is cooled quickly it becomes useless. Prince Rupert's drops and the Bologna flasks are well-known illustrations. Ordinary glassware is allowed to cool very slowly in order to give it toughness and resistance to abrasion. The same is true of cement in comparison with a sandstone or other sedimentary rock. The natural rock may have taken hundreds of years in its formation; the cement has not taken that many hours. Hence the natural material may be expected to show a tougher structure.

I desire to express thanks to Messrs. F. J. Keeley and W. Baldwin Davis for loan of slides for illustrating the paper.

DISCUSSION.

A. E. Lehman.—How were these slides, especially the slides of igneous rock, prepared in relation to the ground?

Henry Leffmann.—I do not think they represent any particular choice in that respect; the making of a specimen depends a little upon chance. The operator strikes the stone and when he gets a chip which is sufficiently large and flat to encourage him to grind it, he does it.

Mr. Lehman.—Are the sections all of the same thickness?

Dr. Leffmann.—No. The grinding is carried only as far as necessary. When the rock is crystalline, the grinding need not be carried to so thin a section. Rocks having more or less opaque materials in their composition require close grinding.

Mr. Lehman.—Have you measured it at any time—the minimum thickness of the materials?

Dr. Leffmann.—No; I could not give the figure. It is done largely by judging the appearance of the rock. It is cut thin enough to destroy any effect of color in the rock itself. When the rock is to be examined under polarized light, the section is often cut especially thin. The operator stops as soon as possible, because it is a tedious process; the section is not cut any thinner than necessary. The thinner the section, the more difficult it is to handle it.

Walter Loring Webb.—Are the specimens soaked in any material analogous to paraffin?

Dr. Leffmann.—No; simply fastened on a piece of glass and ground.

Mr. Lehman.—Is not Canada balsam used?

Dr. Leffmann.—Yes, as a fastening material. Sometimes special studies on rocks are made by etching with hydrofluoric acid, but that is not taken up in this paper; it is another phase of the subject.

The President.—Would you say that, having a knowledge of the microscopic structure of building stones that had weathered well, a similar microscopic analysis of other stones would indicate similar weathering qualities, or would a chemical analysis have to be taken in conjunction with the microscopic?

Dr. Leffmann.—It would be necessary to refer back, of course, in a combination of any system of this kind, to a stone of known durability, and determine its characteristics, and then make them in a measure standard. There are, however, specific conditions in these stones that serve to determine their untrustworthiness. Stone containing a notable amount of pyrites, for example, would be disapproved. To establish this as an engineering question it would be necessary to start with well-known classes of stone that have the necessary durability and other qualities, to ascertain their characteristics thoroughly, and then endeavor to approximate to these in other stones.

In its geological relations, this question is much more thoroughly developed, but it will have, I think, engineering relations in time.

M. R. Pugh.—I think that some years ago there was some investigation made in regard to the depth of weathering, due to the atmospheric corrosion, and of gas, etc., on specimens of stone. I am not sure where, but of certain buildings

and monuments of known age. I wish to inquire whether there is any investigation as to depth of weathering, or microscopic investigation of the chemical changes, or physical changes due to these chemical changes that occurred in that way which would give any guide to a more thorough understanding of the weathering of rock masses.

DR. LEFFMANN.—I think that information is obtainable to a large extent in the recent work of Merrill on "Rocks, Rock Weathering and Soils,"—a large volume, issued a couple of years ago. It is an American publication which goes into the subject very thoroughly. It has a series of chapters on rock strata and the nature of rock masses and contains many illustrations and descriptions of rock weathering and numerous microscopic and macroscopic examinations are given. The general questions in regard to the conditions of weathering are now largely understood. The principal work, or rather the first work, in the studying of rocks was by an Englishman (Sorby), about 1850; but, as has happened with several things England has started, it has been left to Germans to develop. The first coal-tar color was made in England, but the English did not see the advantages and left it to Germany to control the industry; likewise an Englishman made the first step in the study of rock structure, but it is mostly to Germany that we owe the development of the subject. The practical aspect of the question has been treated pretty thoroughly by Americans.

JAMES CHRISTIE.—The accumulated experience of centuries indicates the probability of the behavior of various stones. Locality and climate are important considerations. The syenite that endured for centuries in the dry climate of Egypt, suffered rapidly in the example of the obelisk in Central Park, New York. Many instances are recorded where stone that gives good service in the country has failed in the atmosphere of large cities. Old buildings that survived under the conditions of past time are yielding to the influences of the smoky atmosphere of recent years. The staining of stone surfaces, so evident in some structures recently erected,—and probably arising from the decomposition of metallic particles in the stone,—is more apparent in the city than in the country, and in one section than in another.

Many methods have been proposed and applied for predetermining the utility of stones by accelerated chemical tests; also numerous methods of treating the surface of stone in buildings, for water-proofing and preservative purposes. The appearance of stone as taken from the quarry is sometimes deceptive. Some of the mica-schist, abundant in the northern suburbs of this city, is quite soft and friable when freshly quarried, but hardens and endures satisfactorily afterwards. It is found in good condition in old buildings that survived the past century. On the contrary, some of the shaly limestones that present a good appearance at the quarry weather badly subsequently. An example of this was the stone towers of the original Suspension Bridge at Niagara, which decayed and were considered so unsafe as to justify their removal. Doubtless there is much to be learned on the subject by study of the micro-structure on the lines illustrated in the discourse of Dr. Leffmann.

HENRY H. QUIMBY.—We have in the same quarry different grades of stone, apparently of the same composition, but differing slightly in color and very much in strength. We may have at the bottom of the quarry a stone which is very hard and at the top of the quarry a stone which splits up very easily. Now, will

the microscope enable us to determine whether the stone which is offered for use will be durable or not; that is, from the upper layer or lower layer? That would be a practical application of the science in examining stones under the microscope.

Dr. Leffmann.—I think that after proper preliminary study these problems could be solved by the microscope assisted by the other resources of petrology.

Wm. Copeland Furber.—What was the result of that law case in which the specification called for granite and another stone was offered?

Dr. Leffmann.—The stone was rejected. The parties who objected to that being considered granite gained their case. Several experts were called on each side, but the weight of the evidence was that it was not a granite within the meaning of the term, and the contractor was required to furnish other stone.

If it be in order to make a few remarks, I would say that I hoped that Mr. Schumann would be here this evening. He had mentioned to me an instance which was interesting in this connection. A sandstone in Ohio which has a pretty appearance and is suitable for building work is subject to the objection that it is impregnated with a small amount of petroleum, which of itself is not visible, but gives the stone a greasiness which attracts dirt. These oily places become dirty, and the stone becomes spotted. This is a point that could be determined by even a chemical examination and shows one difficulty from an artistic point of view that might often escape notice.

E. G. Perrot.—What classification do the blue and black stones come under?

Dr. Leffmann.—They are limestones, depending upon the amount of foreign matter in them.

Mr. Furber.—What proportion of carbonate of lime does the Conshohocken stone contain?

Dr. Leffmann.—I do not know; but the section shows a considerable amount. It could not be used to make quicklime, on account of the quantity of silica, which would make a silicate and prevent the lime from slaking.

COMMUNICATED DISCUSSION.

William Copeland Furber.—There are several points in Dr. Leffmann's paper which will bear discussion. One point particularly, regarding his reference to the practice of sometimes not being too definite in the matter of names in a specification for stone.

There are two courses open to the architect and engineer in specifying building stones—one is to specify certain quarries or products of certain localities, the qualities of which he knows, which course is apt to raise the price of the stone by excluding other bidders and keep his client from the use of similar stone, as it is also likely to bring him the criticism of the excluded bidders. The other course is to specify generally what he wants, such as the specification referred to by Dr. Leffmann, for instance, "Maine granite," which instead of working an injustice to the bidders gives a distinct advantage of a wide range of choice to his client and permits the offering of a stone with which the architect or engineer may not be particularly familiar, but which may be in every way suitable.

The designer of a structure is, or should be selected for his knowledge, judgment and integrity. Much is properly left to his judgment, and if he serves his client faithfully there will be little harm come to any one. The average run of contractors are not likely to suffer because some leeway is given the architect in accepting

or rejecting materials. It is entirely justifiable, therefore, in writing the specifications for certain materials which are not *made to order*, to be not *too* specific.

Another matter which has been referred to here was the trimming of a granite building with a softer stone. I do not know the facts in the instance cited, but it is not an unusual thing when building with a hard stone to use a softer stone for the finished or dressed surfaces and carvings, because of the ease of dressing and often because of the economy. Some of the harder stones cannot be satisfactorily dressed and do not lend themselves to ornamental treatment of any kind. The cost of dressing stone has very frequently a great deal to do with its selection. Some stones work easily under the tool and others are worked only with great difficulty. This fact is recognized in the division of the stonecutter's trade into "hardstone" cutters and "softstone" cutters.

The hard stones that reach this market are the granites and blue stones. The soft stones are the limestones, the marbles, and the sandstones. The principal soft stones used here in Philadelphia are the Indiana oolitic limestone, which can be easily dressed and resists the weather, and the marbles from New England and Georgia, which are also easily worked. The Pennsylvania blue marble is a good stone, but its color is against it. Some of the brownstones which are used here are very soft and rapidly disintegrate; numerous examples can be found in this city of the destruction of brownstone. The lower stories of the Bourse were trimmed with a soft brownstone, which, owing to its rapid disintegration, had to be treated externally with paraffin. The brownstone trimmings in the B. and O. R. R. station are rapidly weathering away. This is due, I presume, to the further oxidation of the oxid of iron which gives the stone its color.

From an architectural and esthetic point of view, the building stones are valued for their color, or lack of it, their texture, their durability and strength, and for the facility with which they can be dressed.

As Dr. Leffmann says, there has been but little effort made thus far to judge building stones by any other test than that of experience, yet I fear that until the mechanical and chemical structure of rock and the inter-relation of these structures is more fully understood than it is to-day our chief reliance will be on experience. The augmented freezing test which has been applied to specimen rocks has not proved conclusive or altogether satisfactory, and owing to the local variations of stone in the same quarry, it is doubtful if the experience test will ever be superseded for practical uses. Nevertheless every encouragement should be given to scientific inquiry, so that, as Dr. Leffmann suggests, our real knowledge may be extended and our reliance on experience be rendered less necessary.

Stones both natural and artificial sometimes exhibit curious changes of form. I have seen a piece of marble slab, one inch in thickness, exposed on the exterior surface of a building, warp like a wooden board. I have also noticed that Portland cement pavements sometimes warp with raised edges, just as a piece of wood might warp. I have never heard any satisfactory explanation of these changes of form of non-fibrous rigid materials.

I append a table giving some comparative costs of dressing granite, limestone, and marble, and the cost of such stone set in the walls of a building.

Ordinary New England granite, such as used in buildings, costs about 80 cents per cubic foot in the rough delivered in Philadelphia, and prices range from this

to $3.00 a cubic foot for the finer grades of monumental stone. The cost of dressing granite per square foot is about as follows:

For plain surfaces—

10 cut work (10 cuts to the inch),	$1.00 to $1.50
8 cut work (8 cuts to the inch),	.60 to .80
6 cut work (6 cuts to the inch),	.60

Machine dressing saves about 12½ per cent. over hand work.

The cost of soft stones is as follows:

Indiana or similar limestone,	80 cts. per cubic foot in the rough delivered in Philadelphia.
Dressing and tooling,	25 cts. per square foot.
Bedding and joint facing,	15 cts. per square foot.

Blue stone costs about the same for the rough stock, but the cost of dressing is about 50 per cent. more.

Marble of the cheapest grades, such as used for building construction, costs per cubic foot for 4-inch, 6-inch, or 8-inch sawed ashlar, about	$1.25
The freight from New England is about	.30
The cost per cubic foot delivered in Philadelphia is therefore about	$1.55
Second-grade white veined marble such as that in the new addition to the Fidelity Trust Co.'s Building on Chestnut Street below Fourth, costs per cubic foot about	$1.75
Freight,	.30
Tooling the surface (5 or 6 cut work) per square foot,	.20
Pointing, setting, and hauling,	.50
Incidental charges, including moulded work incidental to a large building, office charges, and profit,	.75
Making the cost of such stone set in place average for the completed work per cubic foot about,	$3.50

The finished cost of stone in large quantities set in a building is about as follows:

Granite,	$3.50 per cubic foot.
Marble,	$3.50 " " "
Limestone,	$2.50 " " "
Brownstone,	$3.00 " " "
Bluestone,	$3.50 " " "

PAPER NO. 1013.

THE SIMPLEX SYSTEM OF CONCRETE PILING.

CONSTANTINE SHUMAN.

Read June 3, 1905.

WITHIN the last three years has been developed a method for constructing foundations known as the Simplex system of concrete piling, which has proven itself so thoroughly reliable and economical that it must be recognized among the standard methods of foundation construction, and hence is well worthy of careful consideration. First adopted by Captain Sewell, Corps of Engineers, U. S. A., for some extensive and difficult foundation work at the Washington Barracks, this system has rapidly spread, until now it is being used in all parts of the country and forms the foundation of many large and heavy structures, as well as light ones, in all parts of the United States.

The use of piles can be traced back to times before history began, as the lake dwellers of Europe are known to have constructed their dwellings sometimes on piles, and sometimes on foundations kept in place by piles.

Many years ago the idea of building up a pile of some other material more durable than wood suggested itself to engineers, who adopted the method of driving a wooden pile, or some other form, down into the ground, withdrawing same and filling the hole with moist sand well rammed into place, thus highly compressing the total mass of the ground and forming a very solid foundation of what is generally known as sand piles. This might be considered as being the first intermediate step between wooden piles and concrete piles.

The continued demand for some permanent form of pile which could defy the action of air and water as well as other enemies, soon brought many minds to bear on this subject. Some thirty years ago a patent was taken out in the United States for a method of producing a cement or concrete pile which consisted in driving a solid steel tapered form in the ground, withdrawing this and then filling the hole with concrete. This, as far as is known, was not commercially worked however, and would be impracticable in most ground, due to the tendency of the ground to collapse before the concrete could be put in. At

the Paris Exposition concrete piles 36 inches in diameter, and 30 feet deep, were produced by dropping a conical plumb bob weighing 10,000 pounds from a height of 30 feet into the ground, hoisting it up again, and dropping into the same hole, and thus continuing until the required depth had been reached, and then filling the hole with concrete. This method was very expensive, however, and only possible in fairly hard ground. It does not appear to have been used further.

Among the first to produce a concrete pile which was put to actual

Fig. 1.

use was the French engineer Hennebique. His method is to prepare a strongly reinforced concrete pile in a mold, letting it set until thoroughly hard, and then driving it in the same manner as a wooden pile. This driving requires some special features, particularly the drive-head which fits on top of the pile, and which is arranged to contain sawdust in a confined space. This head during the driving has the effect to deaden the blow of the hammer and prevent the sudden shock on the pile, and in this way to lessen the destructive effect.

This system requires the preparation in advance of a great many piles, as they could hardly be driven in less than thirty days' set, and the shipping and handling of all the piles necessary on a piece of work. Besides Hennebique's pile there are several other forms of reinforced molded piles which are allowed to set hard and then driven.

The next form of concrete pile was produced by Raymond, who makes use of a collapsible tapered steel driving form, around which is tightly fitted a thin sheet-iron shell. The combined form and shell

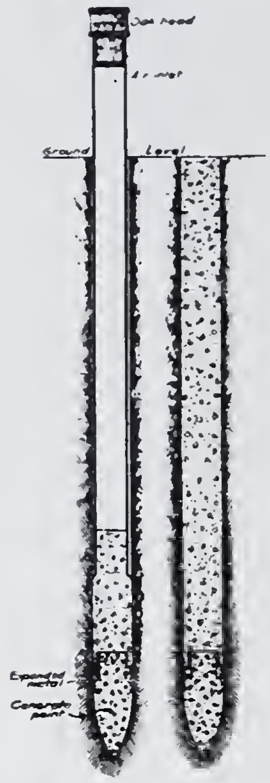
Fig. 2.

are driven into the ground to the required depth, the form is collapsed and lifted out, leaving the shell in the ground, the interior of which is then filled with concrete and rammed. The resulting pile consists of an iron shell surrounding a concrete core. The shell in time rusts away.

The Simplex system of concrete piling, which forms the subject-matter of this paper, was the next in the field. In this system is used a driving form composed of a strong steel tube of large diameter, the

lower end of which is fitted with a pair of powerful toothed jaws, which close together tightly, forming a well shaped point for penetrating the soil while being driven down into the ground, and capable of opening automatically to the full diameter of the tube while being pulled out, and affording an unobstructed passage for the concrete, which is deposited into the hole through the tube, simultaneously with the pulling. The point of this driving form so strongly resembles the head of a giant saurian that it has come to be known as the "alligator"

SIMPLEX CONCRETE PILING SYSTEM
The Cranford Paving Co.
Home Life Building,
Washington, D.C.



—Fig 2A.— Fig 2B.—
PREPARATORY REMOVABLE PILE
WITH DETACHABLE POINT.
Method for use where the earth
is soft or marshy, or where quick-sand or water is encountered.

Fig. 3.

point, a name which was suggested by the darkies who first worked with it.

The gradual development of the apparatus and the methods used in the Simplex system form an interesting study. The first idea brought forth was to drive a wooden form into the ground, pull it out and fill the hole with concrete. This form was quickly superseded by a form made of steel which was used quite extensively in actual practice.

The next step in the process of improvement was to construct a

driving form consisting of a heavy steel tube, into the lower end of which was fitted a reinforced concrete point, which had been previously molded and allowed to set hard, the point being provided with a shoulder on which the tube could bear. This concrete point with the tube on top, would then be driven down to the required depth, after which the tube would be withdrawn, leaving the concrete point below to form the base of the pile, the concrete being simultaneously filled into the hole, through the tube, and rammed. This method requires a molded concrete point for each pile. The reinforced-concrete points were thoroughly practical, but it was found that cast-iron shell points

FIG. 4.

could be used to better advantage and gave more satisfaction. This method of using loose cast-iron points and a driving tube is still used to some extent, but the "alligator" point form is rapidly displacing it.

The next radical improvement of the system was the introduction of the "alligator" point. While the use of the concrete driving points and the cast-iron points was thoroughly practical and reliable and formed an effective method of introducing plastic concrete deep into the ground, still the points were an item of expense and necessitated keeping a stock of them on hand, in order to be in a position to start work on short notice; also, the shipping and handling of the points occasioned further expense and inconvenience. In this direction

there was a good opportunity to do away with some inconvenient features, as well as to lessen the cost of the finished pile. It was realized that if this link in the chain of operations could be eliminated, another step toward true simplicity would have been attained. A hollow form, that could without the use of auxiliary members, adapt itself to be closed at the lower end and exclude the soil while being driven into the ground, and then to open itself and permit the concrete to pass through while being pulled out, would be the ideal of simplicity. All these features are embodied in the "alligator point" driving form.

As carried out in actual practice, this form is constructed substantially as follows. A stock length (about 20 feet) of 15 inches O. D. pipe, ½ inch metal, is reinforced at the upper end by means of a band of ½ inch boiler steel, 18 inches wide, rolled into a cylinder to fit tightly around the pipe and riveted to it by means of three rows of 1 inch rivets, 8 rivets to the row. The rivets are countersunk and have slightly oval-shaped heads, which does away with any unnecessary projections that would interfere with the operations. This band has been found necessary to prevent the upsetting action of the hammer, and its depth (18 inches) has been found by practice to be the minimum to prevent the buckling of the tube, which usually manifests itself in the production of an annular welt just below the band. Even this powerful band with equally powerful rivets does not entirely prevent the upsetting of the metal and the loosening of the rivets. It seems well-nigh impossible to build anything which will entirely resist the repeated blows of a heavy hammer, the only solution being to build all the apparatus of such a rugged nature as to reduce the punishment to a minimum, and it may be noted that these fundamental principles have been followed—namely, ruggedness, heavy riveting, and few parts; no bolts can be permitted anywhere. Four large holes are bored ninety degrees apart through the band and pipe, to accommodate the two inch pins which connect the pulling shackle to the form.

To the lower end of the pipe is riveted a cast-steel sleeve having the same inside diameter as the pipe but of 1½ inches thick metal, making the outside diameter 17 inches. The pipe is turned off true and fits with a driving fit into an 8 inches deep socket turned into the sleeve. Two rows of twelve 1 inch countersunk rivets with flattened heads connect the sleeve to the pipe. To this sleeve are attached two cast-steel jaws in such a manner as to permit them to swing freely.

These jaws are segments of a true cylinder the same size as the sleeve, namely, 14 inches inside diameter, and 17 inches outside diameter, formed by two planes, one cutting in at approximately 30 degrees to the axis, and the second at right angles to the first and intersecting a little short of the axis. When brought together they form a sort of clamshell point, absolutely tight and well adapted for penetrating the soil, but when hanging open they form a true cylinder of the full

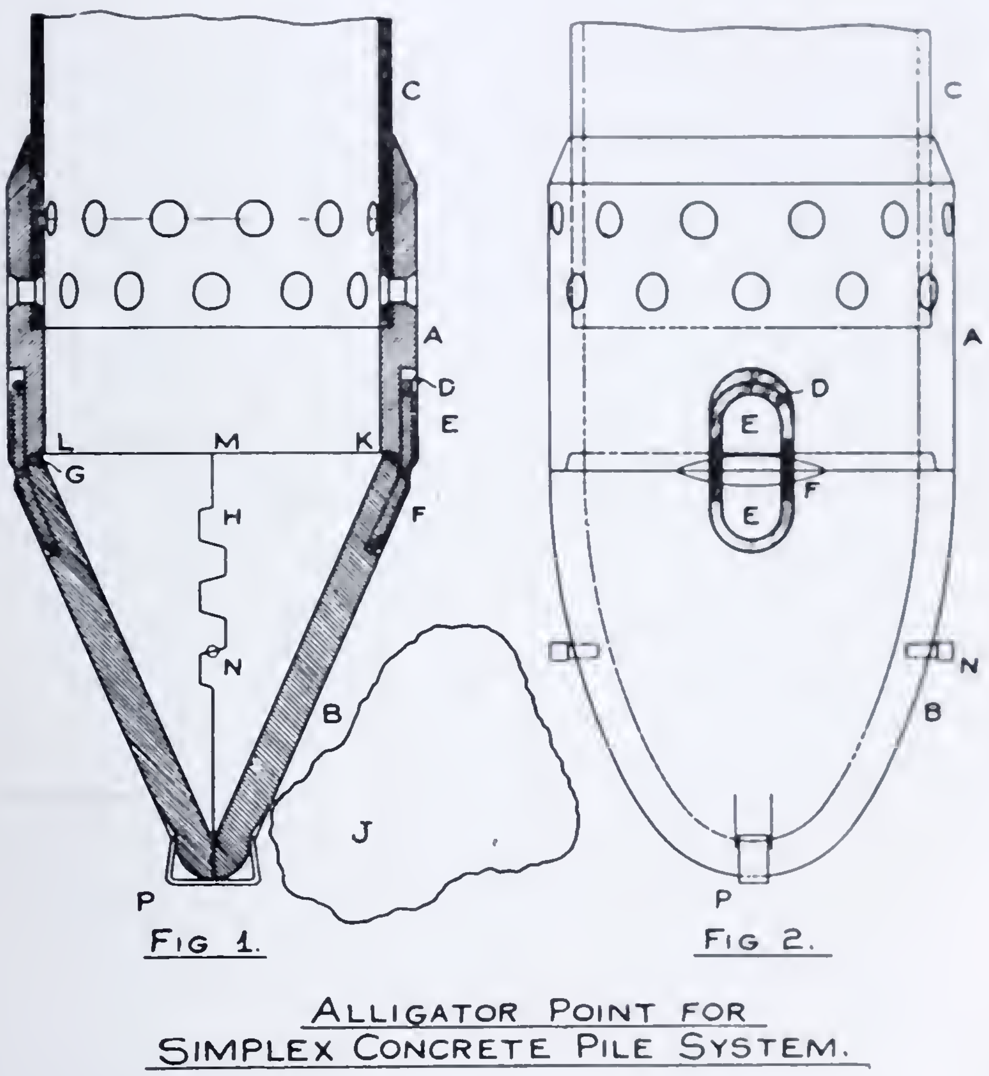


FIG. 5. FIG. 6.

opening of the pipe above, thus giving a straight and unobstructed chute for the passage of the concrete.

To describe this thoroughly it is necessary to refer to a diagram. Figure 5 is a section through the "alligator point" at right angles to the plane of contact of the two jaws; and figure 6 is an elevation from the front of the jaw. A is the sleeve attached to the pipe C. B, B are the jaws, fastened to the sleeve by means of the endless half inch steel cable loops D, which pass around the lugs E, E respectively on the sleeve and jaws. These cables lie beneath the surface, in pockets

cored to receive them, and are covered over with Babbitt metal, with the exception of a small space at F, which is free to bend. If these cables stretch or wear away they can be readily replaced. All joints are machined. The socket shaped joint at G, prevents the jaws from sliding off bodily or spreading. The teeth at H perform a very important function. The interlocking of the jaws binds them together so that they must act as one solid piece. If the point should strike a boulder J, it would have a tendency to deflect and tear asunder at K,

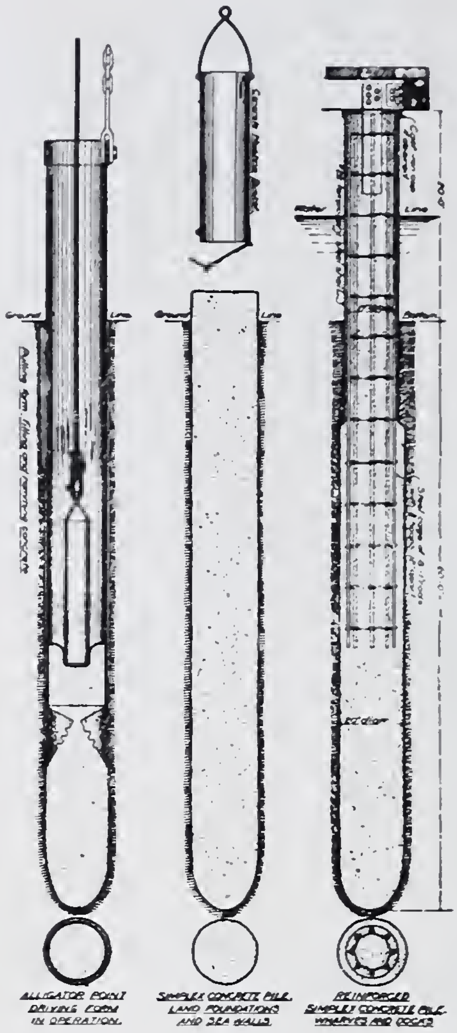


FIG. 7.

but before any separation could occur, the increased pressure at L would establish equilibrium and relieve the strain on the cable. If the jaws were not interlocked there would be rotation at M, causing a frightful strain on the cables. This was learned by sad experience. The jaws are usually closed together and held by two small tapered pins, which are shown at N. They can, however, be held closed by means of a small clamp at P which is destroyed during the driving and comes off when pulling.

Thus built up the driving form consists of a stock length of large

diameter pipe, reinforced at the top with a band and fitted at the bottom with an alligator point. Such a driving form is altogether about 22 feet long. If a longer form is required, additional lengths can be coupled to it. This is done by means of a ½ inch boiler plate three feet wide rolled up in the shape of a cylinder to fit tightly around the outside of the pipe and riveted to each section by means of three rows of 8-1 inch c.s. rivets with flattened heads.

Fig. 8.

The standard driver used in this system is built on the same general plan as the ordinary pile driver, but it is much stronger, heavier, and has some special features. The rollers on which the driver rests are of 10 inches O. D. pipe by ½ inch metal with holes bored through at the ends at right angles to each other, to accommodate the rolling bars, which are made of a crowbar rounded at the ends. The chocks are of cast-iron. When the rolls have been properly greased, the driver will roll and slide without undue force being required. The leads are

made up of 2 pieces of 8 inch × 14 inch Oregon pine 60 feet long tapered at upper end to 8 inches × 8 inches. The faces of the leads are protected by 8 inch steel channels bolted on with countersunk bolts. Just back of the leads and bolted to them are two pieces of 6 inch × 14 inch Oregon pine 50 feet long, which reinforce them and take up the strain of pulling the form, after it has been driven down. On top of these timbers is a sliding purchase cap, from which is suspended the pulling tackle, consisting of one quadruple steel block and a quintuple steel fall reeved with a $\frac{5}{8}$ inch diameter plow-steel wire rope which runs over a single steel block and thence to the engine, thus giving the pulling strength of ten ropes. The steel blocks used are manufactured by the Boston & Lockport Block Co., and are of a special type, as the regular blocks manufactured were found to be entirely too weak. The hammer used weighs 3000 pounds. The engine is of any approved type of hoisting engine with two drums and two 8 × 12 cylinders. On the top of the driver are mounted three sheaves; the middle one for the $1\frac{1}{2}$ inch manila hammer line, the one on either side for the 1 inch bucket line and rammer line.

With the above description of the apparatus the process of producing a concrete pile can be more easily understood, and it is substantially as follows: The driving form is swung up into the leads, the jaws being closed. It is lowered until it rests on the ground and has buried its nose some inches in the soil, when the pins are removed, the jaws being then held together by the pressure of the soil. On the top of the form is placed a steel drive-head with a tenon underneath to engage the pipe and provided on the top with an oak block to take the shock of the blow. The form is driven until it has reached the required depth. The hammer with the drive-head attached is raised to the top of the leads and toggled by swinging out the purchase cap carrying the pulling tackle. The fall is connected to the driving form and made ready for pulling. The rammer, which is a cylindrical cast-iron weight 6 inches in diameter and weighing 300 pounds, is lowered to the bottom of the form and a target is fastened in the rope flush with the top of the form. The rammer is raised half-way up in the tube and a bucketful of concrete, hoisted in a special bucket provided with a falling bottom, is emptied down the tube, striking the bottom with considerable impact. The rammer is lowered until it rests on the concrete, the form is pulled up until the target on the rammer line is one foot above the top of the form, which gives evidence that the jaws have opened, and permitted the concrete to pass through with the

exception of a one foot head of concrete left in the form to prevent any particle of soil from getting into the concrete. The concrete is well rammed by raising the rammer and permitting it to fall frequently on the mass already in place. Then the rammer is raised half-way up in the tube and a second bucketful of concrete emptied; this process being repeated until the hole has been entirely filled and the form withdrawn. When the form leaves the hole, the jaws are usually much clogged with mud and concrete, which must be removed before the point can be closed again. This is effected by means of a $\frac{1}{2}$ inch steam hose run from the boiler and provided with a $\frac{3}{16}$ inch nozzle. Wherever the steam strikes, it instantly removes all mud, and by virtue of its great pressure is enabled to go into all joints and blow out the dirt. The jaws are then closed and the form is ready for another pile. The method above described has been varied to some extent in practice, so that a number of buckets may be emptied in succession before pulling, and frequently the entire form has been filled before the shell was moved.

A pile formed in this manner is a true concrete pile; that is to say, a pile in which the plastic concrete has been well rammed directly into the surrounding compressed earth and is then allowed to set undisturbed and attain its full hardness, without being afterward subjected to any hammering. This intimate contact with the earth means that the concrete has entered the pores of the soil and increased the coefficient of friction. Any stones or boulders which have been encountered and pushed aside have been cemented to and made a portion of the pile, thus affording a great many projections into the surrounding soil. This result is also brought about by the portions of stones in the aggregate being forced outward into the surrounding soil by the ramming to which the concrete is subjected. It has also been demonstrated that when a boulder has been displaced during the driving process a cavity is actually formed where the boulder was originally located, into which the concrete is forced, thus forming an extending ledge which is capable of furnishing a true bearing at that point. The significance of this is more striking when we consider that the bearing power of soil is usually estimated to be about twenty times that of the friction on the sides of the pile. This might be compared to the construction of a thrust bearing for a shaft, where additional thrust surface is obtained by means of thrust collars turned on the shaft. This result is happily indicated in Figure 8, which shows an exposed pile where this action has occurred. This ramming of the

concrete directly into the earth, and the cementing to the sides of the hole, with the consequent great side friction, cannot occur in the use of wooden piles nor in any of the other systems of concrete piling. As the Simplex pile maintains its full diameter all the way down to the point it presents a great area for end bearing, down in the firmest strata, where it has the most value. This great diameter also has the effect of producing a much greater compression of the soil even

Fig. 9.

down to the lowest depths, which effect could not be produced by any pile which does not maintain its large diameter down to the bottom.

The advantages of Simplex concrete piles over wood are so obvious that it is scarcely necessary to mention them, but we cannot afford to pass them by. First and foremost, the concrete piles are of a permanent nature, and once constructed will never need repairs. They are not subject to rot, nor can they be attacked by fire. In the case of some recent wharf fires it was found that the fire had actually burned

down into the heart of the wooden piles. They can be driven through hard upper strata soils, and can pass any ordinary obstructions where a wood pile would fail, and will turn any ordinary sized boulder aside. At Washington a brick sewer was punctured top and bottom and the form driven completely through. At Pittsburg a 6 inch water main was burst by the form.

The most dangerous enemy of the wood pile in sea water is the teredo. This little worm attacks the pile from the outside anywhere

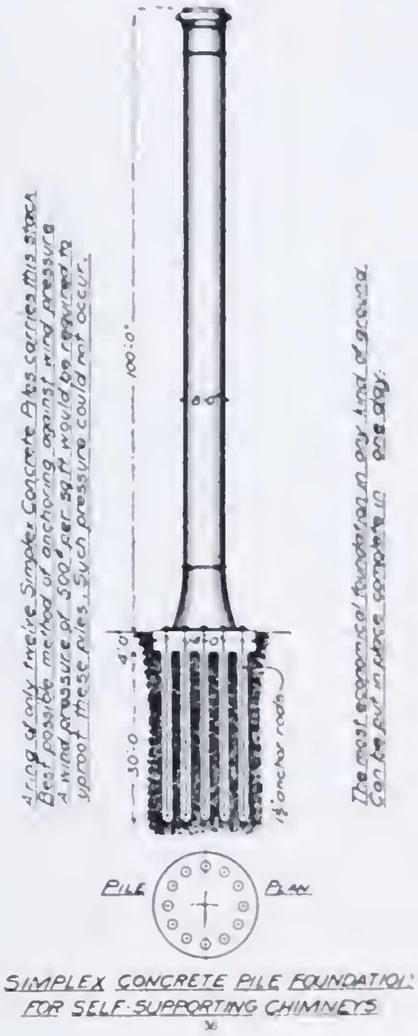


FIG. 10.

below high water and, feeding as it progresses, it bores at a rapid rate until it has honeycombed the pile so effectually that the strength is entirely gone. This is doubly dangerous from the fact that its action is not noticeable from the outside without the most careful inspection. The destruction of a pile in one year is not at all uncommon, and it has frequently occurred that piles have been destroyed by them in three months time. The concrete pile is entirely immune to any attacks of this nature.

A concrete pile can be used to advantage for all the purposes for

which a wood pile is used, besides having some special fields where a wood pile could not be used. For any ordinary foundation work the plain concrete pile as described above is used, and in cases where it becomes necessary it can be reinforced to any extent. For wharves, piers and docks, where the pile must be built up through water, a light iron shell is used to act as a mold for the concrete until it has set, after which the mold may be removed if considered advisable. Such piles, where they must project up many feet above the soil, are very strongly reinforced, in order to give them great resistance to cross breaking. For retaining walls a row of reinforced concrete piles may be built deep enough to get a suitable resistance to overturning, after which the spaces between the piles may be filled in with concrete walls. For machinery foundations which are subjected to vibration strains, it would be a wise plan to reinforce the concrete piles to prevent any possibility of rupture.

A unique field for the concrete pile is afforded by the foundations for large stacks and chimneys. For such a purpose a ring of piles may be driven just under the anchor bolt circle (see Fig. 10), each anchor or bolt running well down into the center of each pile in order to obtain a strong hold in the pile as well as to reinforce it. In this way a great mass of concrete may be saved, as the overturning action is resisted not by dead weight, but by the resistance of the concrete piles to being uprooted.

Where there is lack of head room to drive a long wooden pile, a long concrete pile may yet be driven. To effect this a number of short sections of pipe are employed, so arranged that they may be quickly coupled and uncoupled. One section armed with an alligator point is first driven down, a second section is coupled on to this and again driven down, and so on until the desired depth has been reached. The pulling and filling proceeds as previously described, each section of pipe being removed as fast as it becomes necessary.

In many cases the economy of concrete piling over other methods of foundation is quite marked. Let us assume the case where the upper soil is of a soft unreliable nature and unable to bear the load of the building without resorting to spread footings, and the low water level is considerably below grade. The concrete piling system ignores all these conditions and plants its piles entirely through the soft stuff and into the hard-pan below; the piles are capped with a concrete footing and the foundation is complete.

With any other method we immediately encounter more work and

difficulty. If wood piles are used they must be cut off below low water; this requires sheet piling, excavating, pumping out of water, sawing off of piles and building up of a large mass of concrete in order to reach grade. The time required is much greater. If concrete piers are to be built they must go down a sufficient depth to reach good bearing material. This also requires sheet piling, excavating, pumping and building up of a great quantity of concrete, and the time consumed is enormous. Also there is liability of danger to life and limb from the possibility of the shoring and sheeting collapsing. If spread footings are used the amount of concrete required, together with the cost of reinforcing them, will in most cases cost more than the piling, in addition to which we must consider that the entire building is practically floating on a soft material and subject to all kinds of uneven settlements, from the impossibility of accurately gauging the bearing capacity of the soil, which is apt to vary at the different points. When we drive piles the character of the soil at each point is determined by the penetration, and uniform results are obtained. It has been demonstrated in practice that it is economical to build concrete piles in place of built-up piers whenever the hard-pan exceeds six feet in depth below grade. The rapidity with which a large foundation of concrete piles can be placed saves so much time over the usual methods that it has frequently occurred that the saving in rental of the building amply paid for the entire cost of the foundation.

Where concrete is deposited so far below the surface as is necessarily the case in this system, and where it is so difficult to inspect, the question naturally arises, What assurance is there that there are no voids in the pile, that it is of full diameter, and that while lifting the form no soil has fallen in, thereby destroying the bond? In order to be sure of preventing any voids the concrete is put in as wet as is consistent with good practice, and the persistent ramming to which it is subjected, combined with the impact with which it strikes the bottom when dropped from the bucket, makes the formation of voids an utter impossibility. The quantity of concrete deposited into each pile can be readily ascertained by counting the buckets, and by comparing this with the volume which should be required, it can readily be ascertained that the pile is of full diameter. As stated before, during the process of planting a concrete pile and while the form is being withdrawn a head of concrete at least a foot high is constantly maintained in the pipe, which effectually prevents any soil from falling into the mass and destroying the bond. The target on the ram-

mer rope accurately records all that is going on below the surface and in the interior of the form.

Although many thousands of piles have been planted by this system, and a large number have been exposed and even entirely excavated, yet there has never been any suspicion of an imperfect pile. In all cases they have been found to be a perfect monolith, of full diameter, very rough, and with the earth clinging so tightly to the surface that

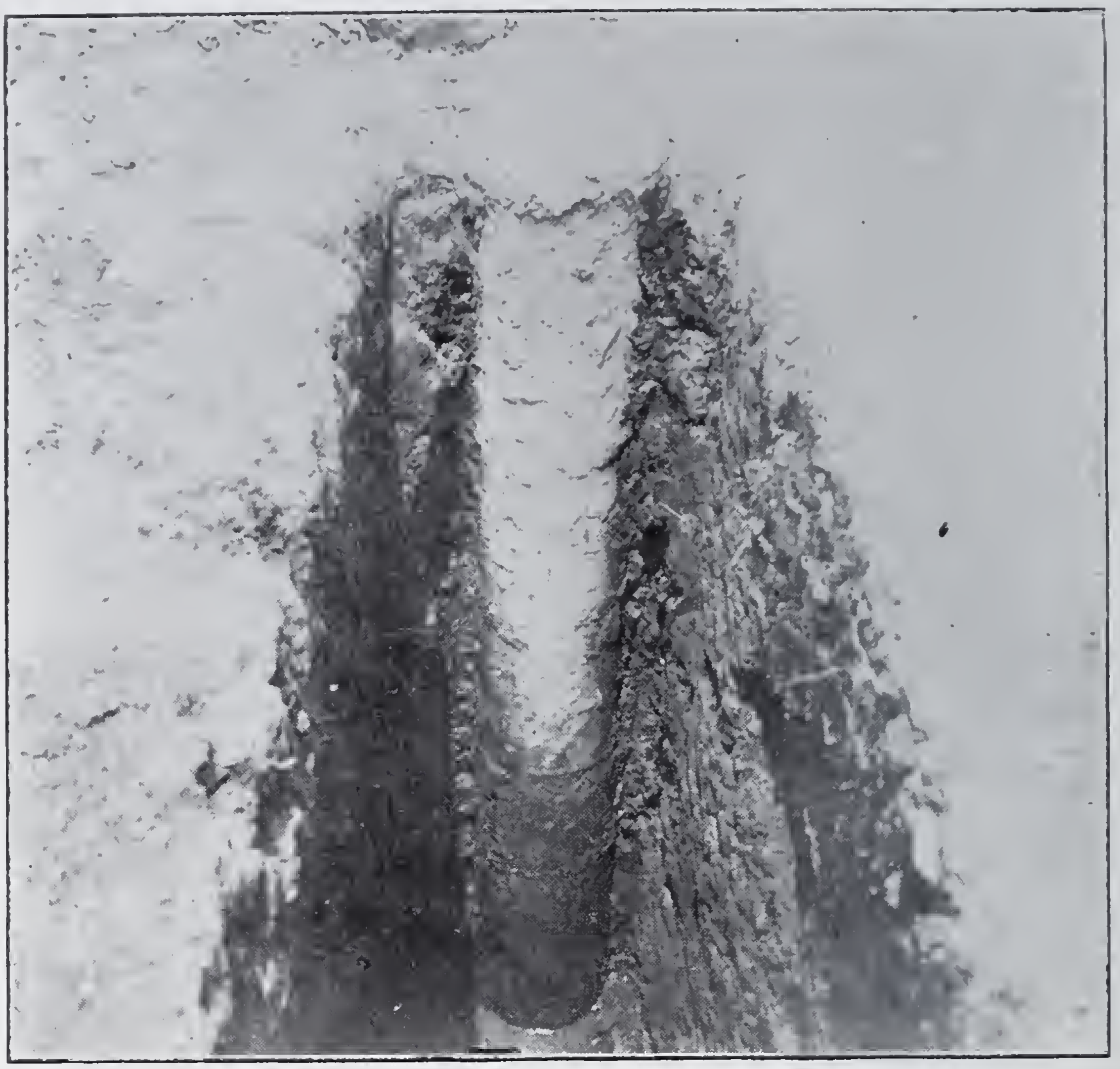


Fig. 11.

it was necessary to remove it with a pick and scour with water before the concrete was bared.

The limiting depth to which these piles may be driven is yet to be determined, as they have been planted to a depth of 55 feet and there was no indication at that point that they could not proceed further. It is easily possible that they may yet exceed 100 feet in length. The usual spacing is three feet centers, but they have often been driven on 30 inch centers. Each pile must be considered as being surrounded with a cylindrical arch of highly compressed earth, which not only

increases its bearing power, but acts as a powerful protection against the distortion of the hole when neighboring piles are driven. When a cylinder is deformed its volume is necessarily decreased, which would necessitate forcing the concrete out of the hole at the surface. This phenomenon has never yet taken place, so it is safe to assume that the piles are never deformed. As a test case, on one occasion at Cincinnati a Simplex form was driven down forty feet, pulled out and driven a second time with only 20 inches in the clear between the two piles. The first hole was left entirely open, and an electric light bulb was lowered into it and the hole carefully watched while the second one was being driven. The hole was flattened one-quarter of an inch on the driving side, but no particles of dirt were knocked off into the hole. Even this slight deformation would not take place if the hole were filled. In this case a conical projectile-shaped point was used, but the "alligator point" has a partially wedge or clamshell shape, which, when turned with its minor axis at right angles to the first hole, will tend to push the soil sidewise instead of toward the hole.

Simplex concrete piles may be driven with their centers within one foot of a masonry wall and yet not disturb it to any appreciable extent. In New York while placing concrete piles for the Produce Exchange Bank Building, the driving was frequently alongside the walls of large office buildings, but the hammering was scarcely perceptible within those buildings. At Cincinnati a row of piles was being driven close to the foot of a large brick wall and, although surveyors constantly took readings of the wall, it never moved out of plumb. This lack of disturbance may be accounted for by the fact that while the soil is much compressed immediately around the hole, by virtue of the short conical point it is compressed in successive comparatively thin layers at a time, and hence does not move the large mass of ground at once.

The first work done under the Simplex system was in January, 1903, at the Washington Barracks, where some officers' quarters, rather light buildings, were to be erected. At first it was intended to build them in the usual manner of running foundation walls below the frost line, but, becoming suspicious of the soil, the engineer in charge placed a test load on it and found it entirely inadequate to carry the buildings. The sinking of caissons, the buildings up of concrete piers, the driving of wood piles and cutting off below low water, and the use of spread footings were all carefully considered and estimated, but each in turn was found too expensive. The Simplex pile

was adopted as being a more economical method, and its use was justified by the final results, which showed a saving of ten per cent. This does not consider the saving of time, which under the present perfected system would have amounted to at least eighty per cent.

The great success of the system at the Barracks attracted attention far and wide, and in a short time it was adopted for a United States Post Office at Lawrence, Mass.; for a P. R. R. train shed at Chester, Pa.; and for the Produce Exchange Bank Building, in New York.

Then after a competetive test it was adopted in the foundation of the Pittsburg Terminal Warehouse & Transfer Company's warehouse in Pittsburg, Pa., one of the largest pieces of foundation work ever constructed in the country. Here were used 4800 piles 17 inches diameter, from 35 to 45 feet long, a total of 162,000 lineal feet, or 31 miles, all of which were planted in three months' time. The lowest time bid for built-up concrete footings was 18 months—a difference of 15 months. The saving in rental of the building for this difference of time was more than the cost of the entire foundation. Each pile was designed to carry a load of 30 tons, and in order to assure himself of their ability to do so, the architect tested a cluster of four piles, selected at random, with a load of 175 tons, and although this load was on the piles for a whole month and close to the tracks of the P. & L. E. R. R., whose heavily loaded trains subjected it to considerable vibration, there was no undue settlement.

Other important pieces of foundation work have been completed, notably in Cincinnati, Louisville, Omaha, Cleveland and Fort Des Moines.

Besides the test above mentioned, the piles have been subjected to frequent heavy loads, usually from 50 to 100 per cent. more than the pile is intended to carry, but in no case has there been any appreciable settlement.

The question of calculating the carrying power of a Simplex pile is a matter that presents some unique features. The ordinary pile formulæ fail to cover the case, as the completed pile has for several reasons a much greater resistance to settlement than the driving form. To appreciate this more thoroughly, let us make a comparison between the form and the finished pile. The driving form has a point adapted for easy penetration, and has a smooth metal surface which becomes polished by repeated driving. Compared to this the finished pile, owing to the efficient ramming, has a very blunt point, and has an extremely rough surface cemented to the compressed earth. When

we review the many extensive formulæ for calculating the bearing power of wood piles, of which some give results five times that of others, we feel that a simple formula which will enable us to compare the driving in different localities and give a fairly close approximation for a safe working load is the one to be desired. The writer proposes the following:

$$B = \frac{2\,W\,H}{(P + 1)} + \frac{2\,W\,H\,a}{(p + 1)\,A\,f} \text{ in which}$$

B = Safe bearing value of finished concrete pile in tons.
P = Penetration at last blow in inches.
p = Average penetration of all blows in inches = length of pile in inches divided by number of blows.
A = End area of pile in square feet.
a = Side area of pile in square feet.
W = Weight of hammer in tons.
H = Height of fall in feet.
f = Coefficient adopted from practice and assumed at 40.

This formula presumes to estimate the bearing capacity of the finished pile by dividing it into two parts—namely, the end bearing power of the pile, and the side friction bearing power.

The end bearing power of the pile is embodied in the first portion of the proposed formula and will be at once recognized as an already well established formula which is both prompt and conservative.

The side friction bearing power of the pile is embodied in the second portion and upon analysis will be found to rest on the presumption that the frictional resistance may be determined from the penetration at each blow of the hammer. This is a sound presumption in most cases, when we consider that the formula is modified by a coefficient obtained from practice. The coefficient assumes that the frictional resistance of a soil is one-twentieth of its bearing power, this proportion being further reduced to allow for the shape of the point. It is not claimed that the formula is exact, but its advantage lies in the fact that it gives accurate comparative results, which should give a uniform foundation, and it is unquestionably well within the limits of safety.

As an example from practice, a pile 25 feet long, 17 inches diameter, required 150 blows, the last blow sinking the pile one-half inch. The average penetration was 2 inches per blow. The skin friction by the formula is estimated at one-sixth of a ton, or 330 pounds, per square foot, which is certainly safe. This multiplied by the side area gives 102 ×

$\frac{1}{6}$ or 17 tons for side friction. The end bearing by formula gives 20 tons. Total 37 tons.

The cost of concrete piling is low enough to permit competition with wood in a great many instances where permanence is *not* a feature. The great diameter of the pile and its better hold on the earth permits a loading twice as great as the wood, so that ordinarily only half the number of concrete piles are required.

A gang to handle one driver consists of a foreman, an engineer, two winch head men and three riggers; and cooperating with them and under orders of the foreman, is a concrete mixing gang of six mixers, one of whom is a man of judgment and who is given charge and held responsible for the proper mixing of the concrete, and for its prompt delivery into the buckets. The cost of labor and apparatus per day for one gang will run from $40 to $50. Under ordinary conditions they will plant from 400 to 500 lineal feet per day. At Pittsburg one outfit working on piles 30 feet long succeeded in planting 31 piles in one day of ten hours; this amounts to 930 lineal feet.

The concrete may be mixed in accordance with any specifications. The usual practice is, one part of first-class Portland cement, $2\frac{1}{2}$ parts of coarse sharp sand and 5 parts of gravel or broken stone. This is a mixture, not too expensive, and yet amply strong enough to develop the full supporting power of the pile.

The system is controlled by The Simplex Concrete Piling Co. of Philadelphia, who have developed it from its infancy and designed all the apparatus, and though they do not contract for the work, they exercise supervision over it in order that no failures may occur due to lack of experience in the handling. All the work is executed by experienced contractors who have been given the license to use the system within a certain territory surrounding their central office.

COMMUNICATED DISCUSSION.

Percy H. Wilson.—The paper thoroughly accords with my views regarding the advantages of concrete piles over wood piles or concrete pier construction.

The uncertainty as to what is happening at the bottom of the pipe during the placing of the concrete must impress every engineer. In driving, the alligator jaws have compressed the earth directly under them to such an extent that the amount of pressure possible to bring from the inside will not open them unless the pipe is raised. They therefore open while raising the pipe, and the concrete at the bottom of the pile assumes very closely the shape of the alligator jaws.

If the pile is driven through soft material, mud or quicksand, for instance, the exterior pressure brought to bear by this material against the alligator jaws must be greater than that interior pressure brought by the concrete and rammer

inside the tube, thus tending to close the alligator jaws. If these jaws are closed, the pile is squeezed, and its diameter reduced.

The bearing of a pile depends upon the compression of the earth beneath the point, and the frictional resistance of the sides, increased by whatever compression of the earth is caused by the taper of the pile. It is a well-known fact that a tapering wooden pile reaches a given penetration much quicker than a pile of cylindrical shape, driven under like conditions. When the Simplex pile is driven without disturbing an adjacent hole, the compression of the earth throughout the length of the pile must be negligible. This pile therefore depends for its bearing power on the compression of the earth beneath the point alone, and to the increased friction due to the mixing of the concrete with the material through which the pile is driven. It is impossible to check the quantity of concrete thus mixed with the surrounding material, and also to tell just how that mixture is effected. Can we be sure that the concrete, when pressed into the earth, retains its bond with the main pile?

The formula used for driving is divided into two sections, the first—the "Engineering News" formula—very commonly used for wooden pile driving; the second, an empiric formula dependent upon the additional friction gained by an unknown mixture of earth and concrete. When this mixture occurs, the tendency is for the diameter of effective concrete in the pile to become reduced. The "Engineering News" formula is one derived from observations taken from wooden pile driving. All wooden piles have more or less taper, and certainly gain in bearing from the compression, and consequent increased bearing capacity, of the earth surrounding them, throughout their entire length. The advantage of this is recognized by the author of the paper, when he says that "the bearing power of soil is usually estimated to be about twenty times that of the friction on the sides of the pile." As the Simplex pile is without any bearing assistance from the ground surrounding it, but depends on its bearing upon the ground directly beneath the point, the "Engineering News" formula should not be used in the calculation of bearing. As the pile depends for bearing upon the compression of earth under the point, the calculation of bearing can only safely be accomplished by use of a column formula.

It was the writer's privilege a short time ago, to see a Simplex pile excavated. (See Fig. 12.) The surrounding earth was good enough to enable the hole to stand without shoring to a depth of twelve feet. The pile, supposedly of at least seventeen-inch diameter, varied from fifteen inches at the top to six inches six feet down. Immediately below that it bulged to thirteen inches, and from there gradually sloped until the point of the pile was represented by practically a point of concrete. The concrete could be washed away with a hose in many places, thus reducing the diameters given above. This pile represented the uncertainties of the system, and emphasized the refusal of the alligator jaws to open at the bottom before the pipe was raised; their liability to close from the exterior pressure of the material through which it was driven; and the ruining of the concrete in the pile by its mixture with the surrounding earth.

Constantine Shuman.—The arguments advanced by Mr. Wilson are not new and are pretty thoroughly covered in the paper, but the writer will try to answer them further in detail and give reasons why they do not apply with any force to the Simplex piles.

Mr. Wilson says: "The uncertainty as to what is happening at the bottom of the pile . . . . must impress every engineer." There is no uncertainty. When the form emerges from the ground the foreman always knows whether he has made a good pile or a bad pile. The volume of the hole made by the form is always accurately known, so if the quantity of concrete deposited equals this volume, it must be a good pile. Among the many thousands of Simplex piles that have been driven, some imperfect piles have doubtless been produced, but in all cases the result was known and perfect piles were driven alongside to compensate for them. It is impossible in any extensive operations

Fig. 12.

to entirely prevent failures; the main thing is to know when failures have been produced and to rectify them immediately.

After the form has been driven it is true that the soil around it is greatly compressed, but it is not necessary to raise the form to permit the jaws to open. As a matter of fact, before any raising is done the heavy rammer is dropped into the point, forcing the jaws apart and producing a very blunt point.

In soft materials, such as quicksand, for instance, there is a great exterior pressure brought to bear against the jaws, and in such cases the process mentioned in the paper is somewhat changed. The form is driven as described, but instead of filling in one bucketful of concrete at a time and ramming, the entire amount

of concrete, mixed as wet as is consistent with good practice, is filled into the form at one operation. On top of the concrete is placed a ramrod with a piston-shaped end nearly covering the entire area of the pipe. On this ramrod the 4000 pounds' weight of the drive-head and hammer is rested. The form is then slowly pulled out, the ramrod squeezing the concrete into the hole with a pressure far exceeding that of the soil, and a full diameter pile is produced.

Mr. Wilson says that when the Simplex form can be driven without disturbing an adjacent hole, the compression of the earth throughout the length of the pile must be negligible. This is by no means the case. The earth is very highly compressed directly around the circumference of the pile, so much so that it

Fig. 13.

requires a pick to remove the soil from a finished pile, but the degree of compression decreases, possibly with the square of the distance, so that when we reach a point 20 inches from the circumference there is very little compression. This cylinder of compressed earth directly around the form is what protected the open hole, mentioned in the paper, from disturbance. The compression of the earth, aided by the rough nature of the Simplex pile, which can be plainly seen on Mr. Wilson's photograph, gives considerable frictional resistance. The Simplex pile compresses the ground much more than an ordinary wooden tapered pile, as its greater diameter displaces much more soil. The only difference is that the short taper of the Simplex form compresses successive layers of the earth as it goes

downward, whereas the wooden pile at every stroke of the hammer is compelled to compress the earth throughout its entire length. As the side surface of the Simplex pile is greater, the compression greater, and the surface rougher, it will be readily seen that instead of the frictional resistance being a negligible quantity, it is greater than that of any wooden or other tapered pile.

Mr. Wilson uses the expression, "the increased friction due to the mixing of the concrete with the material through which the concrete is driven." There is no mixing of the concrete with the surrounding material. When an area of 200 square inches of soil has been forced into the surrounding material, it will be at once apparent that the surface with which the concrete comes in contact must be

Fig. 14.

dense enough to prevent any appreciable penetration of the concrete therein. We never use the expression, "mixing of the concrete with the surrounding material"; we say, "cementing to the surrounding material," which in some cases is a very considerable factor, particularly where gravel or larger stones exist.

Can we be sure that the concrete, when pressed into the earth retains its bond with the main pile? Decidedly we can. Unless some of the surrounding material gets into the body of the pile the bond cannot be broken, and how this can occur, when there is continuously a head of concrete inside the form, under a greater pressure than the soil we fail to see. Mr. Wilson's photograph does not seem to show any disconnected portions of concrete which might indicate a

broken bond. On the other hand, it shows a solid unbroken pile, which might still carry a very good load. It was no doubt an abandoned pile, which was compensated for by an additional one. This is only reasonable, as the dimensions given would indicate that little over half the proper amount of concrete had been deposited, which must have given the foreman and the inspector ample warning. Once in a while such a pile will result through carelessness or accident, such as the breaking of a rope, or the sticking of a form. This is no fault of the system, as such results can always be detected and remedied.

The formula given in the paper has been adopted from practice, and frequent test loads have proved it to be reliable and conservative. Owing to the shape of the driving form the side friction does not come into play until the concrete is in place, hence the driving represents almost entirely end resistance and gives the first part of the formula. The side friction must not be ignored and is added in the second portion. The piles are rarely called upon to carry more than thirty tons. Recently a group of five piles was tested with 300 tons, showing no sign of settlement. This is the heaviest test load ever applied to any piles. (See Figs. 13, 14.)

To get support from the sides of a pile, a taper is of no benefit. Wood piles are tapered because nature made them so, and even these are frequently driven butt end first to obtain larger diameters below, where they are of more service. On the other hand, a taper robs the lower portion of the pile of its size, materially reducing the end bearing and the side surface, both of which are embedded in the firmest strata. To say that a straight pile can have no side support is a fallacy. Shortly after driving ceases, all soils settle back with considerable back pressure. Add to the slope of the sides of the pile the angle of friction resulting from this back pressure, and it will become at once evident that a slight taper on the pile makes no practical difference in the results. This back pressure from the soil is at all times operative, and it is not necessary for the pile to settle before it is developed. If the back pressure did not exist, then a slight taper would not be of service, as the pile would have to settle materially before any side resistance could be developed.

Aside from theory, to give some idea of what side friction on a straight pile is, note what force is required to pull out the form. During the regular operation of the Simplex system when the form is pulled within a few minutes after driving, the usual force required is about ten tons, sometimes twenty. If, on the other hand, the form is left in the ground for a few hours and the soil permitted to close back on it, the force required to remove it is enormous. At Washington a forty-foot form left in for a few hours required a force of 200 tons to pull it. At Astoria a form left in overnight had to be abandoned after 250 tons pull had been applied. This is not rare. It has been found very important never to drive a form and leave it overnight on account of the difficulty of pulling.

PAPER No. 1014.

THE REPRODUCTION OF DRAWINGS OF GREAT LENGTH OR NUMBER.

L. F. RONDINELLA.

Read April 1, 1905.

AT the Centennial Exposition in 1876, the firm of F. Gutekunst & Co., of Philadelphia, exhibited a panoramic photograph of the exhibition buildings printed in one piece, 10 feet long by 17 inches wide. This is the largest photograph that had been made up to that time, and it excited a great deal of interest here and abroad. The panorama was taken on seven glass negatives each 18 inches wide by 22 inches long, so that the details pictured at the edge of one negative were repeated on the adjoining negative. The print was made by seven successive exposures in a frame large enough for one negative, and provided with light-tight boxes for holding the two ends of the sensitized paper rolled up while an intermediate section was being exposed,—a form of apparatus that is still used by photographers in making long prints from several glass negatives. To secure evenness of tone at the edge that was to be printed again under the next negative, it was vignetted or blended with a strip of paper moved by hand,—a process that must have required considerable skill and has since been supplanted by an automatic vignetting screen on the front of the frame. To secure sharp definition in the double exposed parts, the negatives and paper were first marked with guide lines which were afterward made to coincide in arranging them in the printing frame. In a device of this kind the time consumed in arranging the glass negatives and paper is almost as great as that necessary for making the exposures, and good results can be obtained only with great care and skill.

With the modern panoramic camera and gelatine film negatives, photographs may now be made in one piece four or five feet long, and the ordinary printing frame with plate glass to hold a single negative of this size is not unduly expensive nor difficult to manage. But the reproduction of moving-picture films whose length is generally over fifty feet, and the making of blue-prints, etc., from tracings of engineering drawings over seven feet long, is a much more difficult

matter. Such prints can of course be made in sections, in an ordinary photographic printing frame, and pasted together after development; but the amount of time consumed in arranging the exposures and the danger to the negative or tracing are very great; the subsequent joining together takes much additional time, and is not always permanent; and in the case of blue-prints or paper negatives made thus from long tracings it is almost impossible to secure uniform color in the different sections, and continuity of lines where they join.

The possibility of making prints indoors with artificial light has been realized by employing the enclosed-arc lamp in several more or less practical ways, that have made the drafting departments of large establishments independent of adverse conditions of light and temperature out-of-doors. One of the oldest of these arrangements uses the ordinary printing-frame, with a sheet-metal reflector-hood whose rectangular opening covers the plate-glass of the frame, and whose perpendicular cross-sections are parabolas with the enclosed arcs of the lamps approximately in their focal lines. Since the luminous effect varies inversely as the square of the distance from the light, it will be understood, *e. g.*, that with the arc 10 inches from the glass the printing speed would be twice as great as with it 14 inches away, but in the latter case the illumination would be more uniform over a limited area. Therefore, while this method of lighting is not unduly expensive for small prints, it requires a large number of lamps set close together to give even distribution over a big glass, and the first cost and running expense are then very high.

The use of a hollow glass cylinder, with flexible negatives and sensitive material held against its outer surface and illuminated by one or more electric lamps within, is quite an old foreign invention, and has been patented abroad and in the United States in many forms. The most practical method of applying it, is to place the cylinder vertical and gradually to lower along its axis a single arc lamp of very high candle-power. The glass must be rolled accurately in two parts and supported in metal frames; and as the intensity of illumination on its surface is inversely as the square of the cylinder's radius, the latter is usually less than 15 inches, and the greatest possible width of print is therefore less than 4 feet. To insert the materials for printing, the top of the cylinder must be within reach of the operator, and the maximum length of print is therefore less than 7 feet. In common with large blue-print frames, the glass is easily broken by jar or sudden change of temperature, and the average half-cylinder costs about $50

to replace. For making short prints indoors, the glass-cylinder machine is a convenient but expensive apparatus.

For making long prints by sunlight, an old idea that appears to have been independently invented and employed by several parties consisted in using a large wooden cylinder mounted to revolve on a horizontal axle, with the sensitive paper and tracing stretched tightly around its periphery. The earliest record of its use that I find was made in May, 1887, when at the meeting of the American Society of Mechanical Engineers, a blue-print 3½ by 8 feet was exhibited by Prof. Thurston, who stated that it had been made by Prof. E. C. Cleaves of Sibley College, and that it was "probably the largest blue-print yet made by any process." This would now be considered a comparatively short print, yet the cylinder must have had a diameter of nearly 3 feet. In 1899, the North Pacific Railway was using a cylinder 6 feet in diameter for making prints up to 18 feet long, and another party whose name I have forgotten had a cylinder ten feet in diameter for making prints up to 30 feet long. The impossibility of exposing such large cylinders elsewhere than on a flat roof, and the difficulty of manipulating the materials, combine to make them impractical and uneconomical for general use.

This doubtless was the experience at Cornell University, for one year after he had described the machine above referred to, Prof. Thurston exhibited a print 2½ by 14 feet made there on another apparatus which consisted essentially of a thin board slightly longer and wider than the proposed print, covered with felt, and with clamps at the sides and ends to hold the materials smoothly stretched. The loaded board was sprung and (by means of cleats on another base-board) was held with its length in a flat arc, convex upward, and it was exposed in the open air and printed by sunlight. This device occupied less cubic space than a cylinder of equal capacity, and could be loaded and unloaded indoors, and while it was doubtless much lighter and less expensive than a printing-frame with plate glass of equal size, it must have been equally impossible to expose it on a bracket outside of a window, and it probably had to be used on a roof like the large cylinders above referred to.

In 1898, the desire to make some one-piece blue-prints from a very large tracing suggested to the writer the possibility of devising a compact machine in which the blue-print paper covered by the tracing might be kept in close contact while they were drawn at a regular speed under an exposure-opening, through which the light would strike successively

upon all parts of the moving tracing, and thereby make the photo-print beneath it all in one piece. In the first experimental apparatus a dark box, 45 inches long by 24 inches wide, by 6 inches deep, was used, with the top in two parts sliding in from each side to close or to form an opening of adjustable width. Inside were a series of rollers carrying a continuous broad apron of rubber cloth, so arranged that its upper surface was convex and traveled at a regular speed under the exposure-opening, when power was applied to turn one of the rollers. Above this convexed surface and kept in close contact with it was a continuous cover-strip of tracing-cloth, that was drawn off of one roller against the tension of a friction-brake and on to another roller that was revolved by gearing so that its circumference traveled at the same speed as the rubber apron. The rolls of long tracing and blue-print paper were placed on carrier rods inside the box, and their free ends were fed in at one end of the convexed surface by starting the apron and cover, which held them firmly together. The lids were then adjusted to the proper exposure opening, the box was run out through a window on to a bracket in the sunlight, the mechanism was started, and as successive parts of the tracing traveled under the exposure opening, the print was made. When developed the print would show uniformity of color and sharp definition crosswise, but there was a slight blur in the lengthwise direction, due to the fact that as the transparent cover was wound on to the pulling-roller, its circumference and speed were slightly increased, and the tracing was pushed along a little faster than the blue-print paper beneath it. This defect could have been prevented by arranging the transparent cover like the rubber apron in a continuous band traveling over slightly larger rollers, but then there would have been a strip of lighter color across the print at each interval where the joint in the cover came in contact with the tracing, and there would have been two thicknesses of material to print through. So this scheme was abandoned in 1899, but more than three years later a patent was granted to another Philadelphian for an application of the same ideas, with the differences (see Fig. 1) that both conveyors were long rolls of material instead of one being an endless apron, and the lower one was drawn with more or less friction over a "stationary curved bed" instead of over a series of rollers. A second patent granted a few months later to the same inventor, protects the use of "two endless-apron conveyors," and this principle is applied in the Franklin Blue-Print Machine, which will be described later.

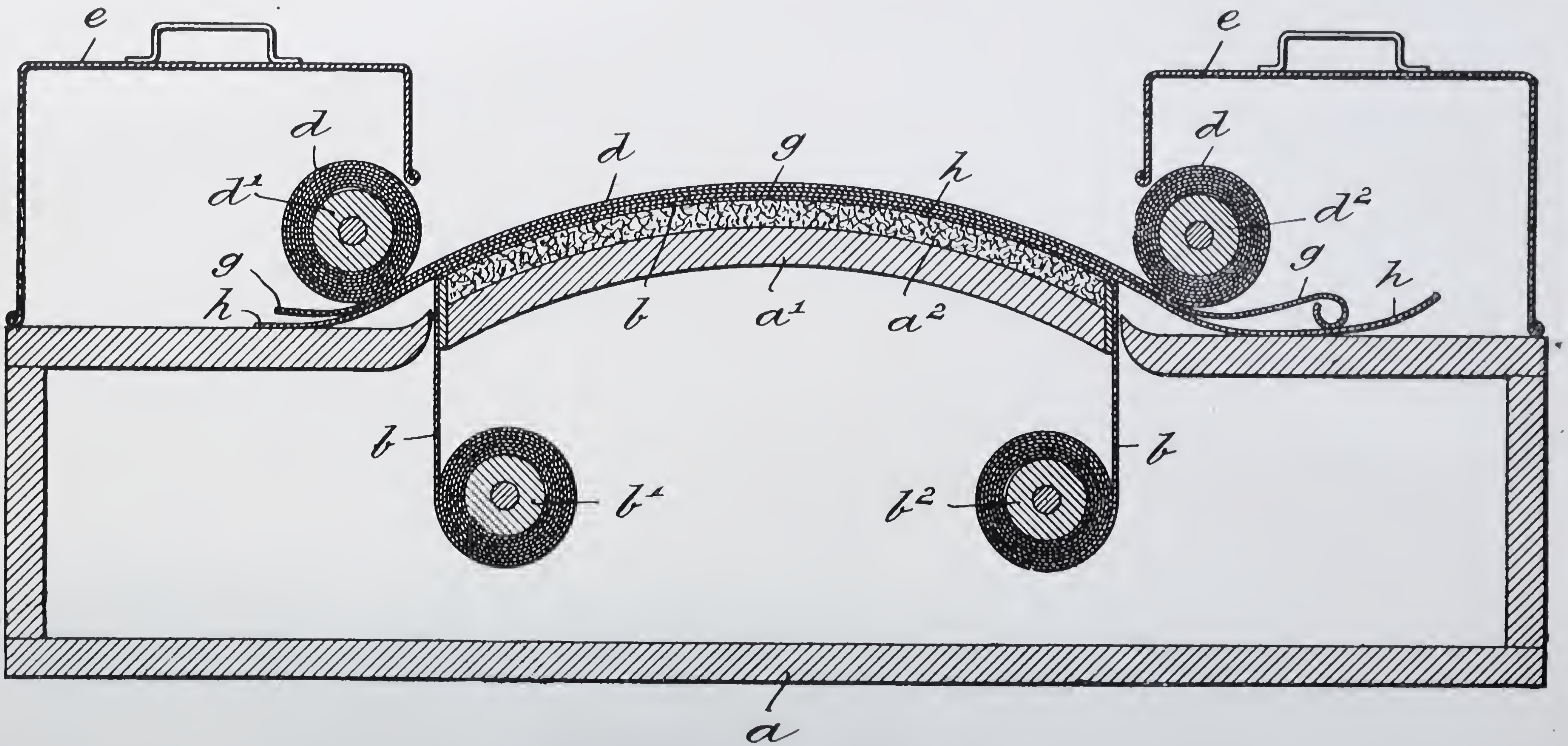


Fig. 1.—Continuous Printing over a Curved Surface.

The next idea and the one which has resulted in the development of the Star Photo-Printing Machine, was to use a horizontal drum of sufficiently small diameter so that it and the materials to be printed, together with the necessary driving and regulating mechanism, could be carried inside of a dark-box or casing, whose dimensions would permit of its being exposed for sun-printing on a bracketed track passing through an ordinary window. In April, 1900, satisfactory prints of various sizes were made in an experimental apparatus containing a drum twelve inches in diameter by forty inches long, and in October, 1900, application was filed for a patent which was issued March 19, 1901. Lack of time outside of regular professional and social

Fig. 2.—Star Photo-Printing Machine, with Casing Closed.

duties has made its development rather slow, and has permitted two later inventors to make an earlier commercial introduction of their machines; but this is the only one now on the market which can be used for sun-printing under ordinary conditions, while for electric-printing it is the least expensive and most rapid for a moderate consumption of current. The construction and method of using the Star Photo-Printing Machine will be understood from a brief description, with the aid of a few illustrations. The machine is made in three sizes for producing prints of any length up to 70 feet, with maximum widths of 30, 42 or 48 inches. A furniture-finished oak casing contains the materials before, during, and after printing, and all of the

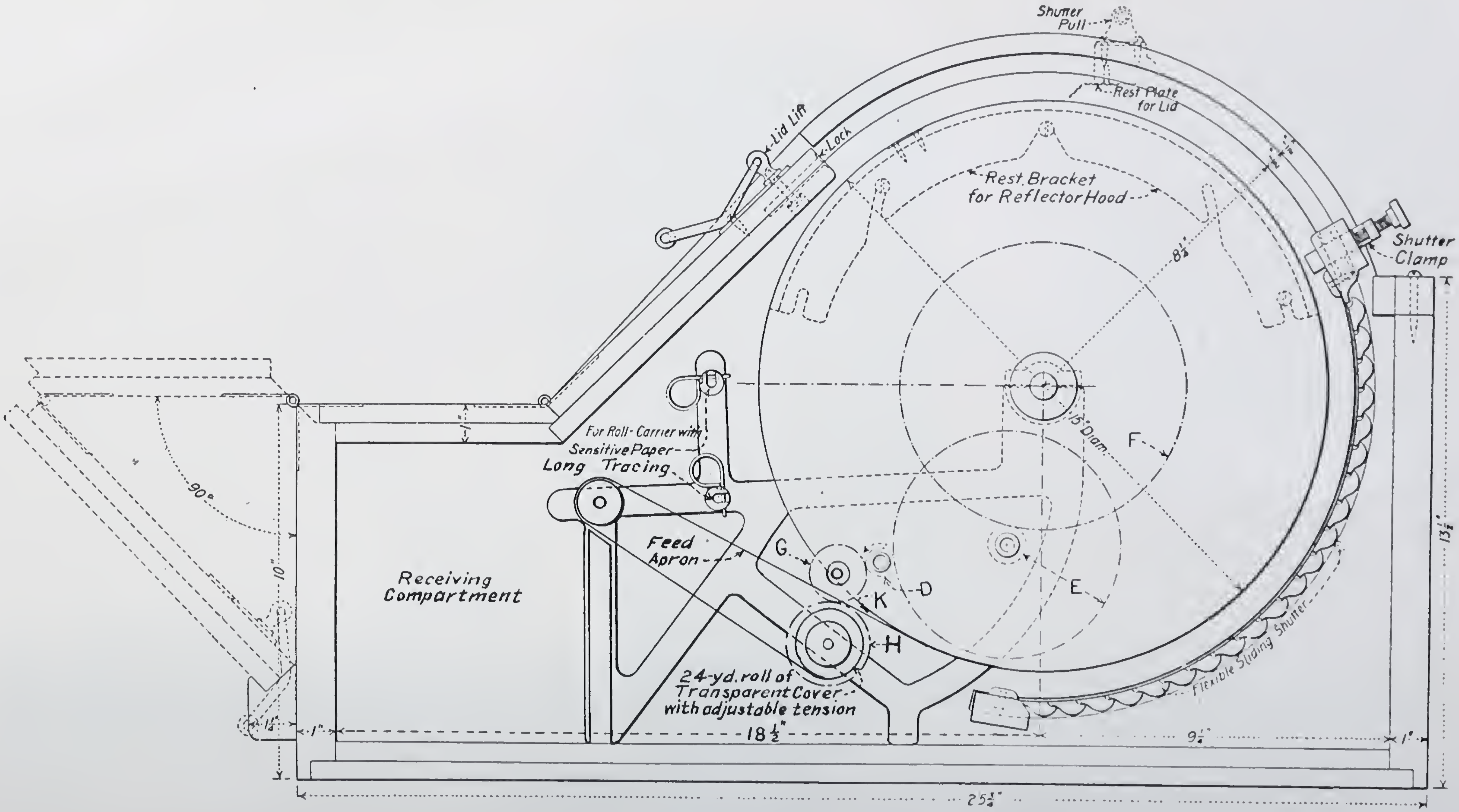


Fig. 3.—Star Photo-Printing Machine, End View of Inside Mechanism.

mechanism, except the 1-20 HP. electric-motor and its reducing gears, which are carried outside of one end. (See Fig. 2.) This casing is provided with ball casters, and may be mounted on a track to be rolled out through an ordinary window facing south for sun-printing, or may be placed in a fully equipped support for electric printing by enclosed-arc lamps, or may be stood on a table with its attached equipment for electric-printing with mercury-vapor tubes. Its top is closed by a two-leaf lid (which may be swung open to rest in three different positions), and by an adjustable curved shutter, so that the exposure-opening can be varied from 0 to 105 degrees for sun-printing, and to 120 degrees for electric-printing, permitting prints to be made by either kind of light with equal rapidity. A lock is provided to fasten the lid to the shutter so that a roll of sensitive paper, or anything else placed inside of the casing, may not be meddled with. (See Fig. 3.)

Under the exposure-opening is a felt-covered wooden drum, to which is permanently fastened the outer end of the transparent cover, —a strip of best quality tracing cloth over 70 feet long, carefully prepared so that it will wind true off of its tension roller and on to the drum, or *vice versa*. Along one edge of this cover, numbers are stamped at every foot to indicate the maximum length of print that may yet be made when part of the cover has been wound around the drum. By carrying the cover-strip from its roll over another roller to the drum, an inclined feed-apron is formed down which the tracing and sensitive paper are carried into contact with the drum at the tangent-point K (Fig. 3), and up which they are discharged from K after printing, and fall into the receiving compartment in the near side of the casing. The tension of the transparent cover may readily be adjusted by slightly turning a wing-nut in a friction brake, so that close contact to the sensitive material is obtained with smooth or rumpled tracings, on thick cloth or thin paper, traveling at any desired printing-speed. The little electric motor that operates this machine is mounted on a bracket at one end of the casing and has its high speed reduced by a spur-gear-couple to a driving spindle, which passes through the casing and carries on its inner end the pinion D. By means of a spring latch, outside the casing, fitting into one of two grooves around this spindle, the latter turning always in *one* direction, is made to revolve the drum and the roll of transparent cover in *both* directions. When the spindle is drawn out, the pinion gears through a second reducing-couple E to the drum-wheel F, to move the drum

and cover forward; and when the spindle is pushed in, the pinion gears through an idler G to the roller-wheel H, to rewind the cover and turn the drum backward, against an adjustable friction at its bearings. The three different forward speeds are slower than the three different return speeds, and both are very regular. Their combina-

Fig. 4.—Support for Star Photo-Printing Machine and Electric Equipment.

tion in double-printing gives nine different durations of exposure and this number may be multiplied by changing an incandescent-lamp-resistance at the top of the motor, without the use of an external rheostat or cone-pulleys, that are employed in other machines.

The support for the Star Photo-Printing Machine (Fig. 4) is made of oak finished like the casing, with angle-iron braces, and occupies a floor-space of 3 feet by 4, 5, or 5½ feet. It is wired so that the binding posts at its top can be connected at once to the mains of a two- or three-wire system carrying 110 or 220 volts, direct current. Enclosed-arc lamps and motor having the same external shapes and dimensions are furnished for either voltage. Each lamp is less than 23 inches high, weighs less than 11 pounds, and has a current consumption of 715 watts; and four lamps are used with the No. 30 machine, five with the No. 42, and six with the No. 48, placed 9 inches between centers. The motor consumes about 40 watts. The lamp is a new type having very simple construction with only two moving parts; it at once establishes and maintains a very steady arc of high actinic power, lasting for about 130 hours continuous burning with one set of carbons. The lamps and reflector are fastened to a suspension-beam which is carried by ropes anchored to the top of the support and passing over double-pulleys, so that only half of the total weight is borne by the operator in raising or lowering the loaded beam. The reflector-hood is hung from two chains so that it can be dropped by hooking down one or more links when the consumption of the carbons brings the arcs appreciably below its focal line.

A Cooper-Hewitt outfit of three mercury-vapor tubes can be furnished for the No. 42 machine, which will give an equal printing-speed with about one-third of the current consumption, so that the greater first cost is soon saved in the reduced expense of operation.

With the machine in its support for electric printing with arc-lamps (see Fig. 5), the shutter and lids are thrown open; the suspension-beam is lowered so that the reflector-hood covers the upper third of the drum's periphery, and the lamps are close to the exposure surface; the switch on the end of the support is thrown-in, lighting all the lamps at once, or those not previously cut out by their individual switches; the spindle is drawn out to gear with the large wheel E (see Fig. 3) and the motor is started by throwing its switch to the point that will give the desired forward speed to the drum and its transparent cover; the tracing or negative and sensitive paper are placed face downward on the feed-apron and are drawn in at K between the drum and transparent cover, and the latter holds them in close contact with the drum while they travel around under the reflector-hood; the forward exposure thus continues automatically until the last part of the tracing or negative appears from under the hood; the

motor is then stopped while the spindle is pushed in to gear with wheel G; the motor is started again, and rewinds the transparent cover tightly around its roller, thereby turning the drum backward with the tracing and sensitive paper still in close contact under the light,

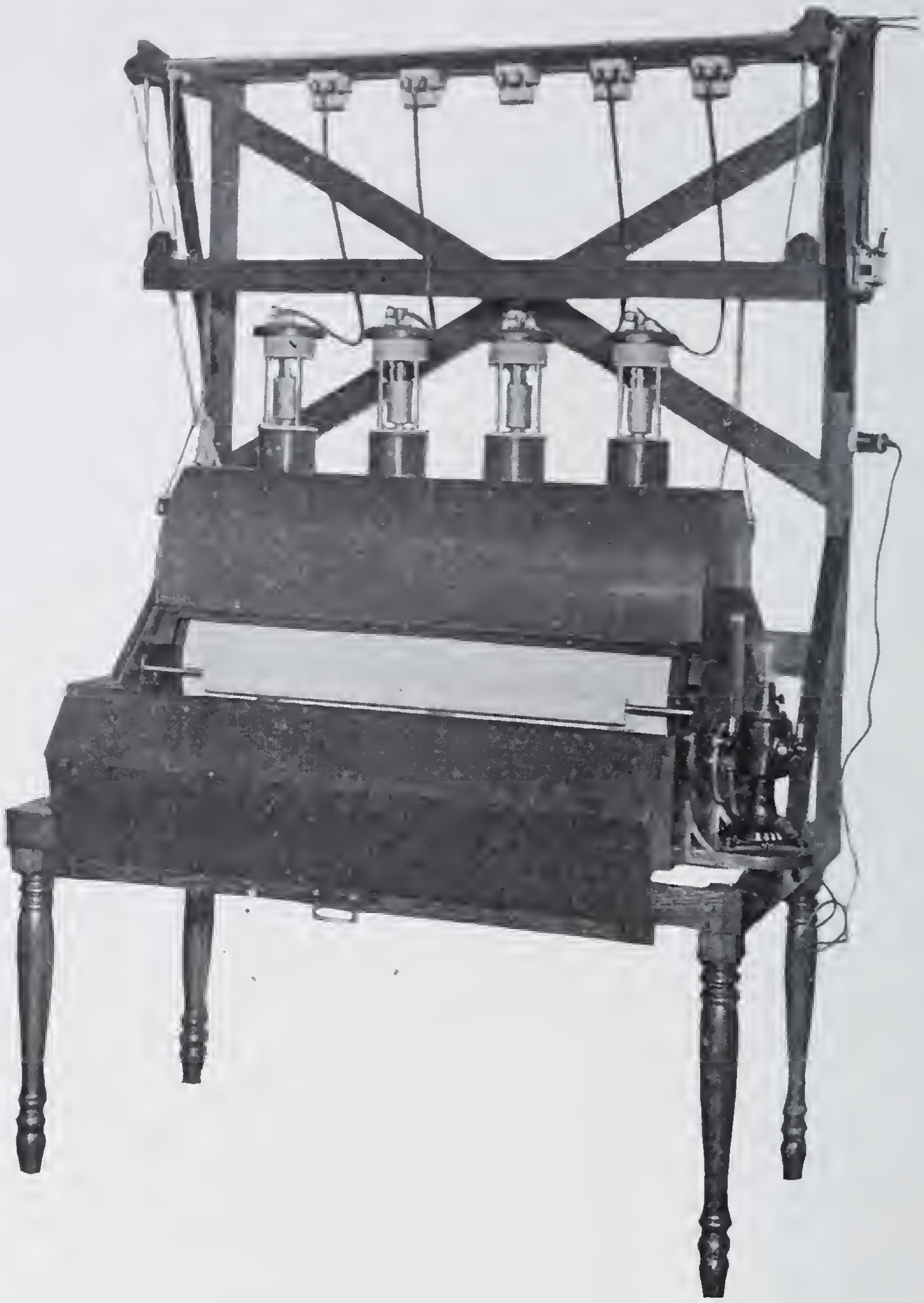


FIG. 5.—AUTOMATIC PRINTING WITH ENCLOSED-ARC LAMPS.

completing the exposure and discharging the tracing and print at K. The machine is thus restored to its original condition.

When making a single long print, the roll of sensitive paper is slipped endwise over its aluminum carrier-rod, which is then inserted into its hole-and-slot bearings at the two ends of the casing; the motor is run

for a moment while the free end of the sensitive paper is fed in at K and held by the transparent cover; the long tracing in a roll is then slipped over *its* carrier, and inserted in its bearings; the motor is started, the free end of the tracing is fed in, and the double-exposure is made as described above. As the tracing and print feed out of this machine, they drop from the feed-apron into the receiving-compartment of the casing; or while the tracing is thus cared for, the print may be rolled

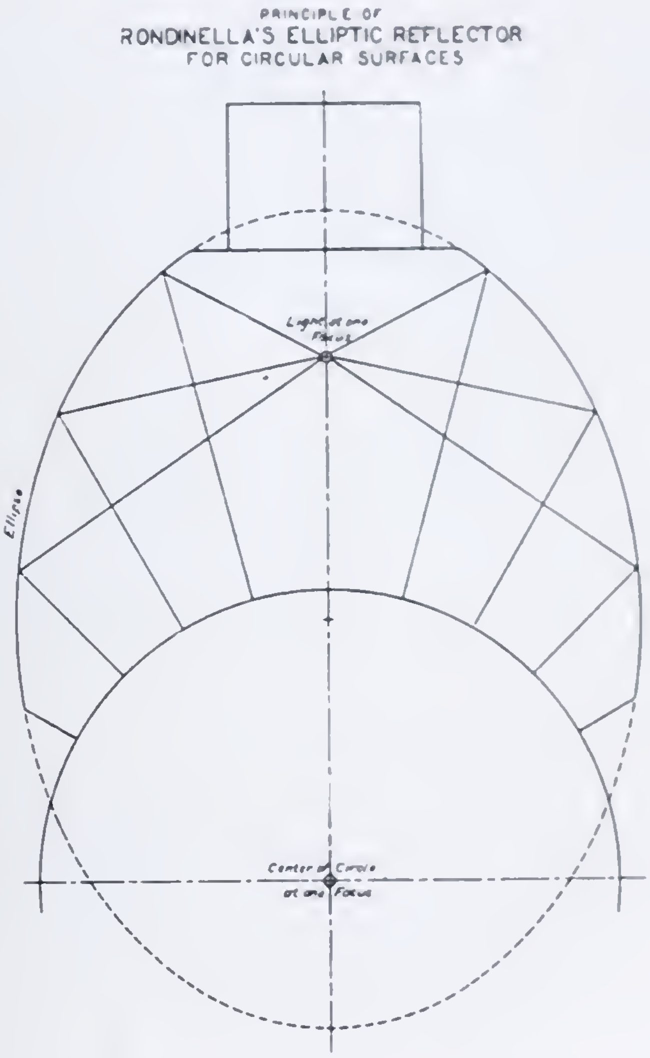


Fig. 6.—For Uniform Distribution of Electric Light.

up by hand ready for development. When making prints from several tracings, the roll of sensitive paper may be used as described above, and the tracings fed in side by side, or one after another, until all have passed under the cover. The exposed paper is then cut from the roll, and fed out with the tracings in reverse order while the printing is being completed.

The best light from enclosed-arcs for electric printing is obtained by placing the lamps directly above the axis of the drum, for the

strongest rays are thrown downward from the upper carbon, and the intensity of illumination diminishes rapidly above an angle of forty degrees to the horizontal. These strongest rays then strike directly on the exposure arc of the drum, and by enclosing the lamps under a reflector-hood, especially designed for the Star Machine, the weaker rays also are caught and reflected directly upon the printing surface, so that *all* of the light is utilized. The superior efficiency of this form of reflector hood (see Fig. 6) depends upon an original application of two mathematical principles of the ellipse, for the invention of which I first put myself on record before the Franklin Institute at its meeting of Dec. 21, 1904. It is well known to mathematicians, first, that a tangent to an ellipse makes equal angles with the two focal radii from the point of contact; and second, that the added lengths of all pairs of focal radii are equal. By using a reflector whose cross-section is an elliptic curve, and placing the electric-arc at one focus, all the rays of light that strike on its inner surface will be reflected to the other focus, and they will all have the same total length. If an equal length be subtracted from every reflected ray by interposing a curved surface whose cross-section is a circular-arc with its center at the second focus of the ellipse, then the reflected rays of light will be all normal to the curved surface, and will be all of equal length and equal illuminating intensity. The elliptic reflector used with the Star Photo-Printing Machine produces this effect by having the lamps hooked in a fixed position to the suspension beam, from which the enclosing reflector-hood is suspended by two adjustable chains, as described above, so that by means of peep-holes in its curved surface its focal line can be made exactly to coincide with all the electric-arcs; and when the beam is lowered until the ends of the reflector touch the rest-brackets at the ends of the machine-casing, the focal line of the reflector is at the proper distance from the axis of the drum, so that the latter would coincide with the second focal line of the complete ellipse. The distribution of the direct and reflected light on the curved exposure surface in the Star Photo-Printing Machine is so nearly uniform, that it is possible to make small prints under its reflector with the drum stationary.

The writer naturally thinks his own machine is the best, on account of its earlier inception, its lower cost, its smaller size, and its greater efficiency; but this paper would be incomplete without at least a brief description of the two other continuous-printing machines that are now on the market. The Franklin Automatic, Continuous Feed, Electric Blue-Printing Machine (Fig. 7) consists essentially of two

strips of transparent celluloid overlapped and cemented at their ends to form endless bands, each mounted on two rollers that are geared to travel at the same speed. The two near sides of these transparent bands are kept in contact by being pressed down on to a fixed convexed surface which is located between the two runs of the lower band, with its chord inclined at about 60° to the horizontal. Near and parallel to the outer run of the upper band is a sheet of plate glass to protect the inflammable celluloid from the heat of the arc-lamps. Motive

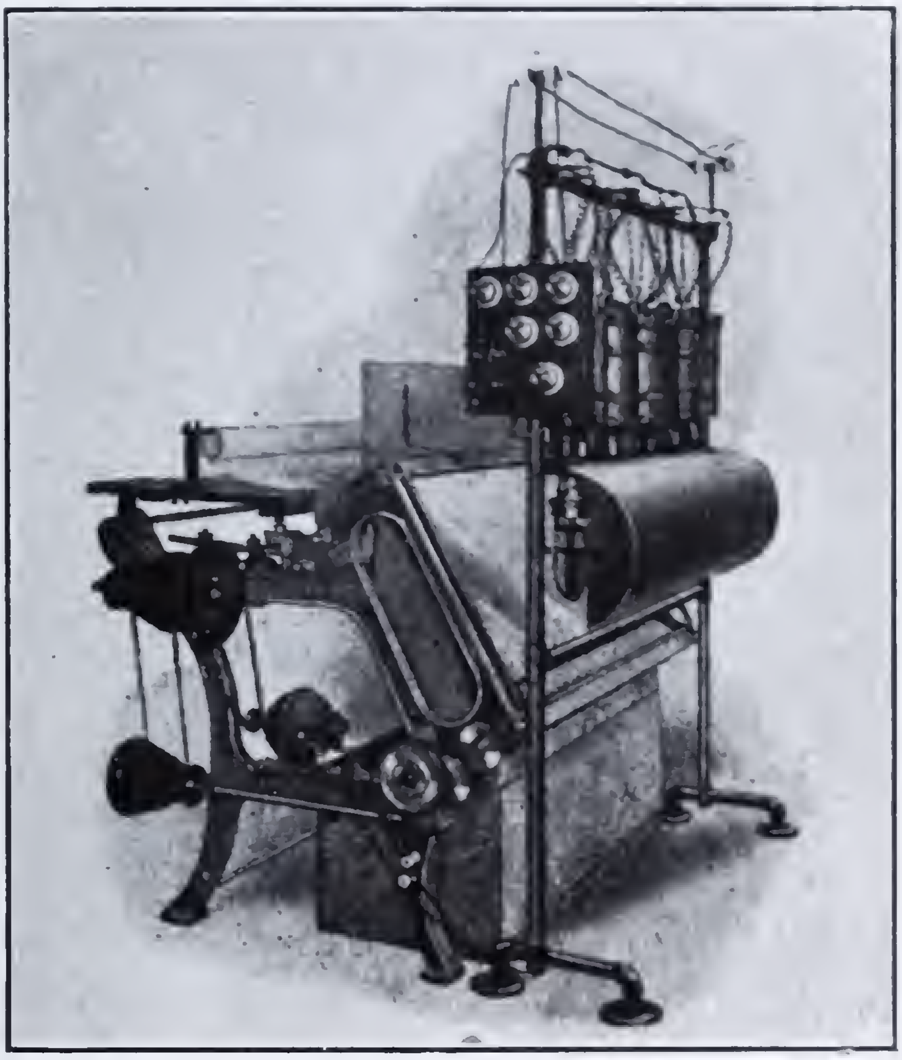


FIG. 7.—FRANKLIN ELECTRIC BLUE-PRINTING MACHINE.

power is furnished by a one-tenth or one-sixth H. P. electric motor mounted on one end of the framework, belted to a counter-shaft which carries a large cone-pulley, from which a second belt runs to a second cone-pulley on the driving-shaft, and this through a worm and reducing-wheels actuates the rollers that carry the transparent bands. The speed of travel of the bands is therefore varied by shifting the belt on the pair of cone pulleys. At one side of the machine a horizontal feed-table is provided, and a perpendicular screen to prevent

the diffused light of the lamps from shining in the operator's eyes and from spoiling the sensitive paper. At the other side, on the floor is a dark box into which the tracings and prints drop after exposure, and an iron framework which carries the enclosed-arc lamps (placed 7 inches between centers) and a reflector, with wiring, switches, etc. In making a print, the tracing and sensitive paper (face upward) are drawn from the feed-table between the contact-surfaces of the two

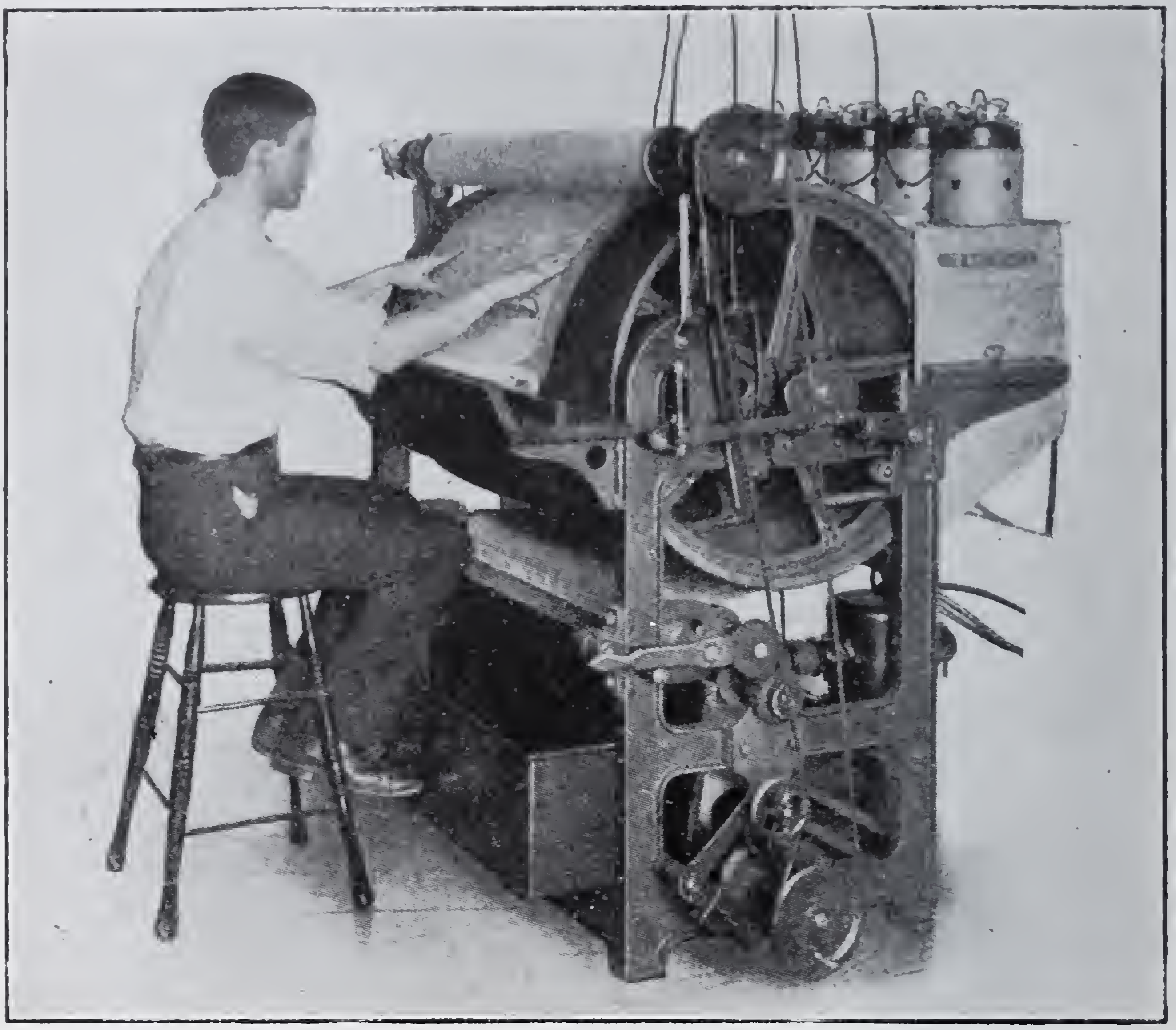


Fig. 8.—Federal Blue-Printing Machine.

bands, over the fixed convexed surface and discharged into the box on the other side of the machine; and during this passage most of the light from the lamps passes through the glass and the two runs of the upper celluloid band, and the print is made. This machine occupies a floor space 5 feet wide by 5 or 5½ feet long, with additional space necessary for the operator at both sides and one end.

The Federal Blue-Printing Machine (Fig. 8) consists essentially of a

wooden drum about 30 inches in diameter, carried in roller bearings and revolved by the frictional pull of a transparent cover that encircles one-half of its periphery. This transparent cover is a 24-yard roll of tracing cloth wound upon a let-off roll which is provided with a friction brake, and the cover is threaded around the drum, through two pulling-rolls, and on to a take-up roll, against which several friction wheels press. Motive power is supplied by a one-fourth H. P. electric motor, belted to a clutch-pulley with a speed regulator, and from there is transmitted to the pulling-rolls through a worm-couple, a bevel-couple, and a spur-couple of gear wheels, on three non-parallel shafts. On the feed side of the machine is a rest-shelf to carry the sensitive paper and tracings, and at the bottom a receiving compartment for the tracings and prints after exposure. On the opposite side of the machine the enclosed-arc lamps (placed 7 inches between centers) in a plane-sided reflector, are carried on brackets fastened to the framework in such a position that the light is horizontally opposite the drum-shaft, and the vertical opening of the reflector encloses about 90 degrees of the drum's circumference. In making a print the sensitive paper and tracing are held face outward against the drum, and pushed up until their ends are caught between the drum and the transparent cover; after which, in traveling automatically half around the drum they are exposed to the arc lights, and finally drop into the receiving box. When the entire length of the transparent cover has been run through the machine, it must all be re-wound on to the let-off roll before further printing can be done. This machine occupies a floor space 4 feet wide by $4\frac{3}{4}$, $5\frac{3}{4}$, or $6\frac{3}{4}$ feet long, and is over 5 feet high.

Where there is a large wash-tank, a long print can readily be developed by folding it back and forth while it is pushed under the water or solution, and it can be dried by hanging it in the same way from a series of parallel wires or cords of moderate length, great care being taken to prevent its tearing while wet. For developing long prints in a narrow tank, and for drying them in a small space, the writer has designed a washing-frame and drying reel that one person can operate. The washing-frame (Fig. 9) is made of ash, finished with spar-varnish, and the metal parts are of brass, aluminum, and zinc, so that water will not injure it. The bottom of this frame is immersed in the water in the tank, which need only be 2 feet wide by $3\frac{1}{2}$, $4\frac{1}{2}$ or 5 feet long. The upper part is made to slide up and down in the lower support nearly 2 feet, so that the top may be on a higher level than the head of the

operator. The exposed print is wound on a roller, which is then placed in bracket-bearings on the lower frame. The hinged strip carrying one of the two rubber wipers at the top of the frame is then drawn up, and a metallic fastener strip (attached by tapes to the shaft of the drying reel) is passed over two aluminum rollers at the very top of the frame, through the wiper opening down under two more aluminum rollers immersed in the water, and up to rest on the front edge

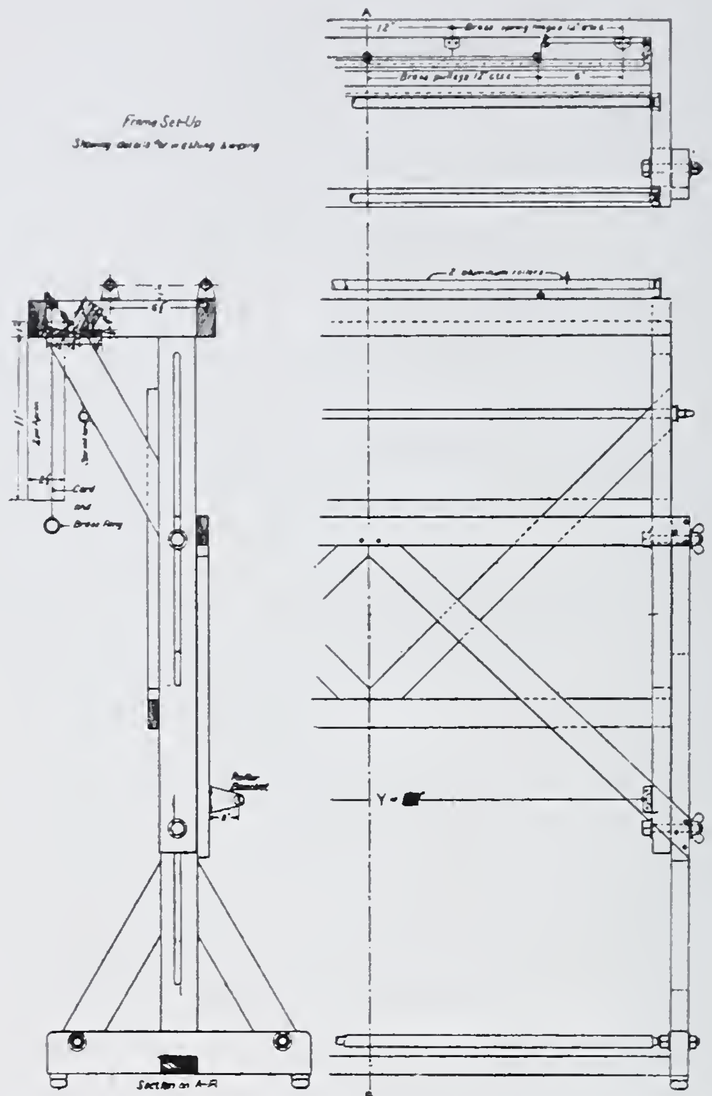


Fig. 9.—Washing-Frame for Long Prints.

of the tank. There the free end of the exposed print is attached to the fastener-strip by spring-clips arranged so as to prevent tearing, and is laid in the bottom of the tank; and (through a rubber hose attached to a faucet) water is turned into a sprinkler-tube that passes back of the framework below the top. Then by winding the drying reel, the tapes, with the fastener-strip and the attached blue-print are drawn back through the water in the tank, and up back of the sprinkler which thoroughly washes the print. When the fastener-strip has passed

through the wiper opening, the spring-hinged wiper-strip is released, and the two rubbers, pressing on opposite sides of the washed print as it is drawn through, wipe off the loose water as effectively as a pair of wringer-rolls.

The Drying Reel (Fig. 10) is capable of carrying 80 feet of material, and consists essentially of a rectangular framework 5 feet high by $3\frac{1}{2}$, $4\frac{1}{2}$ or 5 feet long, suitably braced, and carrying on the inside of its uprights two bracket-bearings with hinged caps, so that they may be tightened with more or less friction around the journals of the reel proper. The latter has a large wooden shaft with three or more grooves in which are wound the tapes attached to the metallic fastener-strip

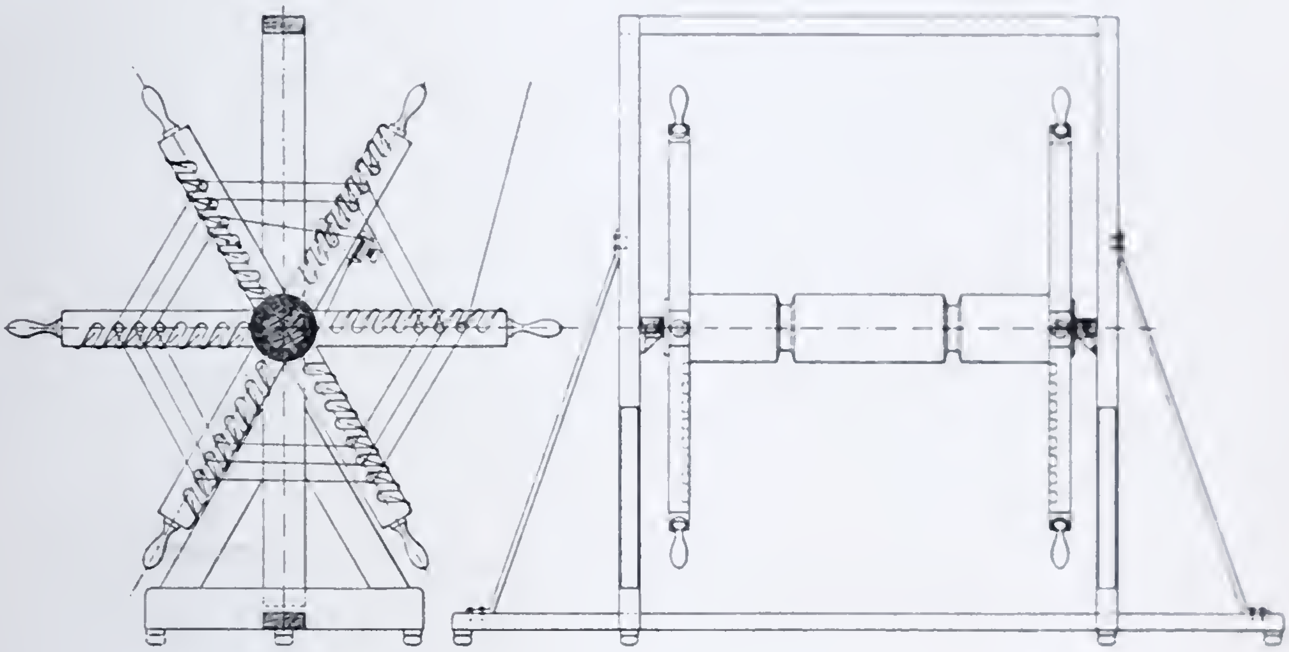


Fig. 10.—Drying Reel for Long Prints.

already referred to; and it carries at each end a six-armed spider with a winding-handle at the end of each arm. In the inner face of the arms circular holes are provided in one spider, and slots with springs in the other; and into these, aluminum tubes are inserted as the reel is slowly turned, and the developed print is drawn from the top of the washing frame around the tubes in the form of a six-chord spiral. The *back* of the print is kept in contact with the tubes to prevent a slight chemical discoloration which would otherwise result, and a little slack is allowed in the winding to allow for contraction as the print dries. Although it takes but a short time for the wiped print to dry, the loaded reel can be lifted from its bearings and an empty one substituted for immediate use if desired.

While the old-style glass printing-frames are perhaps sufficient for those having only a few drawings of small size to reproduce, a machine that will rapidly make good prints of any size in the open air when the weather is warm and the sunlight steady, or indoors by day or night when the outside conditions are unfavorable, will prove a very economical addition to the photo-printing equipment of a large and progressive establishment.

DISCUSSION.

L. F. Rondinella (answering a question).—The speed of electric printing in this machine is about equal to that of clear sunlight through the plate-glass of a large printing frame. For example, the sensitive paper that we have here requires a total exposure of about eighty seconds to make prints either way with the dark-blue color that you see; and with a more sensitive solution I have made equally good blue-prints on this machine with sixty seconds' exposure to electric light or fifty seconds' exposure to sunlight. The unique feature of the machine is its ability to make very long prints in one piece, and it is of course true that for making a single small print a machine is not so advantageous as a blue-print frame; but in a printing-room where it is necessary to make a large number of small prints, the tracings can be fed into the machine one after another on a long roll of blue-print paper, and in that way a great deal of time is saved.

Carl Hering.—A somewhat similar apparatus could be made by simply using a Cooper-Hewitt tube, and slowly drawing the tracing and blue print-paper together over the tube, using the tube as a drum. The paper would then be within about $\frac{1}{2}$ of an inch of the light itself.

Mr. Rondinella.—It might be possible to mount a Cooper-Hewitt tube in that way, so that the tracing and blue-print paper could be carried over as described, but I fear it would not work very well, for it would be difficult to get good contact.

Wm. McClellan.—The Cooper-Hewitt tubes might burn the paper.

Mr. Rondinella.—I think they would at least melt the paraffin in the tracing if brought as close as Mr. Hering suggests. Of course, there is comparatively little heat from the Cooper-Hewitt lamp, but when you put your hand on it you find that it is pretty hot, and if you kept a tracing against it long enough to print, I think there would be trouble. The Cooper-Hewitt outfit that we furnish with my 42-inch machine is a very compact arrangement where the three or four tubes are each in its little elliptic reflector, in a framework which carries the necessary resistance coils on top, and is lowered over the drum to a rest position where the axes of the tubes are two inches from the printing-surface.

The President.—Is there any danger, when turning the drum back, of the tracing or the paper slipping and making a secondary exposure?

Mr. Rondinella.—We have never had that experience. I do not see how it could occur, because they are pressed close together by the transparent cover which is fastened to the drum and completely encircles it. In the other drum-machine which I spoke of, I think slippage is possible, although I have seen very good prints made on it.

F. G. Thorn.—When the print returns the second time past the light, is it removed from the machine or can it be run through again without displacement?

Mr. Rondinella.—Repeating the complete exposure is an experiment that I have not tried, for it is possible to use a speed slow enough to print even through a paper-negative with one forward-and-return run. I think, however, that a short tracing could be run through again if it were desired to do so; but I am afraid that with a long tracing, on account of the skewy character of the tracing cloth, it would probably run in a little differently the second time, and possibly blur the print. If several small drawings are made on absolutely different materials, like tracing cloth and bond-paper, for instance, you cannot get anything like uniform results when printing them together in any apparatus; but if all are made on tracing cloth, there might be perhaps a little darker shade in one than in another, but they could all be good prints.

Mr. Thorn.—If you take several pieces of linen, even off the same roll, handled by different draftsmen, perhaps one will be on the board two hours, another on the board a week; there is also a difference in the draftsmen, one may have a little more moisture in his hand, and the tracings will be a little more opaque. Or one of the tracings may have been in its drawer two years, and the operator has to judge by the linen or paper whether it will give quick results or not, whereas if the operator could examine each print by turning it back, I think he would get much better results.

Mr. Rondinella.—It takes more experience on the part of a photo-printer to see the ultimate color from an undeveloped print than it does to foretell the relative translucence of several negatives or tracings. So if he is familiar with the sensitiveness of his paper, he can judge how long to expose each different negative or tracing. With a *new* lot of paper, when making a print from one tracing in a frame with hinged back he might determine the necessary exposure by bringing in the frame, and examining one end of the print. But when printing from several tracings at one time it is impossible to do that, in a frame or in any other apparatus, without misplacing some of the tracings and spoiling the print. The usual and best way to determine the sensitiveness of new paper is expose a small scrap of it under a tracing in the printing apparatus for a measured length of time, and the character of the developed scrap will show whether a longer or shorter time is necessary for the prints made subsequently.

Mr. McClellan.—How are those long prints dried?

Mr. Rondinella.—The long print on the wall, which is three feet wide, was washed in the washing-frame and dried on the reel described in the paper, and the compactness of the apparatus may be judged from the fact that the printing was done by sunlight on a bracketed track outside of, and was washed and dried inside of, a closet measuring $4\frac{1}{2}$ by 9 feet. The long narrow print was washed by hand in a tank by folding it back and forth in the water, from which it was removed while folded, and then straightened out as each fold was fastened to spring-clips on a drying wire. Of course, the wet print must be wound on the reel or hung from the wire with a little slack to allow for contraction in drying.

W. F. Ballinger.—Would it pay to instal this apparatus, say in an architect's office where blue printing costs from $50 to $60 per month? Can the blue print paper be bought already sensitized or can the operator sensitize it?

Mr. Rondinella.—The paper can be bought already sensitized in rolls of ten

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or fifty yards, which may be carried and kept in the machine; not only for making blue-prints, but for making paper negatives with translucent lines on an opaque background, and positive prints with blue or dark-brown lines on a white background. As to whether the expense of the machine would be warranted in an office whose blue-print bills amount to $50 or $60 a month, I think I can answer without quoting figures, by saying that the cost of the machine would be saved probably in nine months if a boy was already employed who could run the machine; while if it were necessary to employ a boy especially for the purpose of operating the machine, it might take a year to save the cost. Of course, it would not be necessary to pay very high wages to a boy who could operate it, as it requires but little skill.

Mr. Hering.—What is the cost of current per hour for the apparatus, at the usual city prices?

Mr. Rondinella.—For operating this machine on either 110 or 220-volt circuits each lamp requires 715 watts per hour; and, figuring the cost of the current at ten cents a kilo-watt-hour, the expense would be about seven cents a lamp, or less than thirty cents for the four lamps per hour, running continuously. With this machine only, that expense may be avoided by using sunlight when it is strong and clear; but when it is weak or variable, the time saved by electric printing and the more uniform results will compensate for the cost of current.

Eugene D. Hays.—In relation to the amount of heat given out by the Cooper-Hewitt tubes, I wish to say that we place them $1\frac{3}{4}$ inch away from the film of a photographic negative without damaging the negative in any way. That is, $1\frac{3}{4}$ inch in an enclosed frame. Consequently, in a blue print frame, with a little ventilation, we would be able to get at least that close, and that will give us very rapid results. I have been able to secure a very satisfactory print in twenty seconds, printing through glass only, on paper which takes $1\frac{1}{4}$ minutes on the Franklin blue-printing machine for the same result.

ABSTRACT OF MINUTES OF THE CLUB.

Business Meeting, June 3, 1905.—President Comfort in the chair. Eighty-two members and visitors present.

Dr. H. E. Wetherill described an instrument called the "Angleometer."

Mr. Constantine Shuman read a paper on "The Simplex System of Concrete Piling."

The Tellers announced that George B. Harris and Wm. Lawrie Reid were elected to active membership and that John Gwilliam was elected to junior membership.

The Nominating Committee, nominated by the Board of Directors, was announced as follows:—L. Y. Schermerhorn, Chairman, Francis Schumann, E. M. Nichols, Edwin F. Miller and W. B. Riegner.

Business Meeting, September 16, 1905.—President Comfort in the chair. Sixty-nine members and visitors present.

The Nominating Committee, as finally nominated by the Board of Directors, was accepted.

Dr. Henry Leffmann read a paper on "The Microscopic Structure of Building Stones."

The Tellers announced that John W. Meyer and Harry S. Parks were elected to junior membership.

ABSTRACT OF MINUTES OF THE BOARD OF DIRECTORS.

Special Meeting, June 3, 1905.—Present: President Comfort, Vice-President King, Directors Davis, Quimby, and Devereux, the Treasurer and the Secretary.

The Nominating Committee was nominated as follows:—L. Y. Schermerhorn, Chairman, Francis Schumann, E. M. Nichols, Edwin F. Miller, and W. B. Riegner.

Adjourned Meeting, June 12, 1905.—Present: President Comfort, Vice-Presidents McBride and King, Directors Dallett, Davis, Devereux, and Easby, the Treasurer and the Secretary.

The report of the Treasurer for May and June was read and accepted as follows:

May,	Balance March 31, 1905,	$2866.57
	April Receipts,	791.65
		3658.22
	April Disbursements,	838.20
		2820.02
June,	Balance April 30, 1905,	2820.02
	May Receipts,	374.00
		3194.02
	May Disbursements,	443.13
		$2750.89

It was moved and carried that the salary of the clerk be increased from $35 to $40 per month, to date from July 1st.

It was moved and carried that a Tally Register for the use of the Janitor in counting the attendance at meetings be purchased.

It was moved and carried that it is the sense of the Board that Book Reviews of all books sent to the Club for reviewing should be confined to a brief statement of the contents and general subject matter treated in the book, and that they should follow the practice of the Am. Soc. C. E.

Regular Meeting, Sept. 16, 1905.—Present: President Comfort, Vice-President McBride, Directors Dallett, Davis, Devereux, Loomis, and Quimby, and the Secretary.

The action of the President in arranging for the change in the position of Chairman of the Nominating Committee from Mr. Schermerhorn to Mr. Schumann, was approved.

The Finance Committee presented a routine report.

The meeting of the Club of October 7th was appointed a business meeting.

The report of the Treasurer for the months of June, July and August was presented as follows:

Balance May 31, 1905,		$2750.89
Receipts,		
June,	$354.09	
July,	230.95	
August,	302.75	887.79
Disbursements,		$3638.68
June,	422.07	
July,	729.49	
August,	254.61	1406.17
		2232.51
Balance August 31, 1905,		$2232.51

ADDITIONS TO THE GENERAL LIBRARY.

FROM CHAS. D. WALCOTT, DIRECTOR.

Twenty-fifth Annual Report, Geological Survey, Mineral Resources of the United States.

FROM HENRY H. SPRAGUE, CHAIRMAN.

Fourth Annual Report of Metropolitan Water and Sewerage Board of Boston, Mass.

FROM JAMES M. SWANK.

Annual Statistical Report of the Am. Iron & Steel Association.

FROM COMMISSIONER OF PATENTS.

Annual Report for 1904.

FROM SEWERAGE AND WATER BOARD OF NEW ORLEANS, LA.

Tenth Semi-Annual Report for 1904.

FROM HENRY B. KUMMEL, STATE GEOLOGIST.

Annual Report of State Geologist for 1904.

FROM PUBLICATION COMMITTEE.

Volume III, Fire Insurance Society of Philadelphia.

FROM THEODORE A. LEISEN, CHIEF ENG.

Thirty-fifth Annual Report of Board of Water Commissioners of Wilmington, Del.

FROM W. S. BLATCHLEY, STATE GEOLOGIST.

Twenty-ninth Annual Report of Department of Geology.

FROM GEO. S. WEBSTER, CHIEF ENG.

Annual Report for 1904, of the Bureau of Surveys of Philadelphia.

FROM CORINTHIAN YACHT CLUB.

By-Laws, Racing Rules, etc., of The Corinthian Yacht Club for 1905.

FROM GEO. W. RAFTER.

Hydrology of the State of New York.

FROM CHARLES H. RUST, CITY ENG.

Annual Report of the City Engineer of the City of Toronto for the year 1904.